2022
MASSACHUSETTS
CLIMATE CHANGE
ASSESSMENT

2022 Massachusetts Climate Change Assessment

December 2022

Volume III - Regional Reports

Executive Office of Energy and Environmental Affairs

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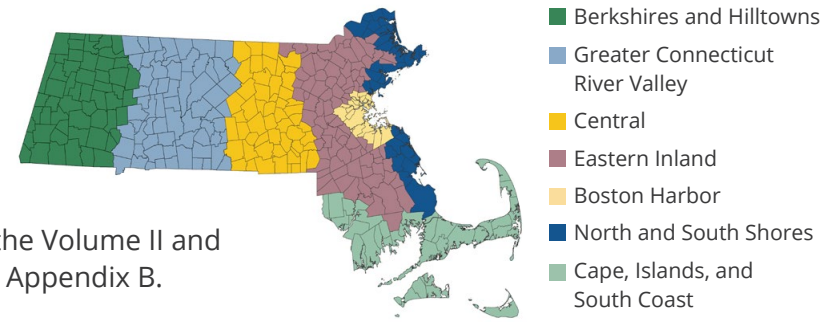
Impacts of Climate Change by Region

Regional and local adaptation action is critical to addressing the challenges of climate change. This volume presents the impacts of climate change in seven regions of the Commonwealth.

Region-specific priorities reflect the unique hazards, natural and built environments, and demographics of each part of the Commonwealth. The sections that follow provide an impacts summary and report for each of the following:

- Berkshires and Hilltowns Region
- Greater Connecticut River Valley Region
- Central Region
- Eastern Inland Region
- Boston Harbor Region
- North and South Shores Region
- Cape, Islands, and South Coast Region

Climate Assessment Regions

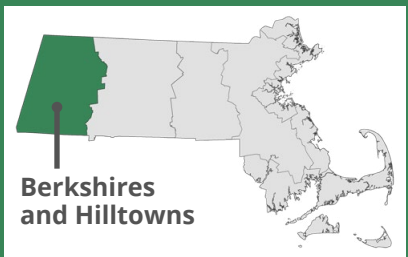


Further detail on methodology can be found in the Volume II and a list of cities and towns by region is provided in Appendix B.

Berkshires and Hilltowns Region Climate Impacts

The Commonwealth is already experiencing climate change impacts. The Berkshires and Hilltowns region is particularly vulnerable to climate hazards such as increasing temperatures, more extreme precipitation, and associated flooding. An understanding of the current and future impacts of climate change allows community decision-makers to best tailor adaptation plans to meet the specific challenges faced in this region. This report summarizes the highest urgency climate impacts across Human, Infrastructure, Natural Environment, Governance, and Economy sectors for the Berkshires and Hilltowns region.

The highest urgency impacts are based on a review of the latest climate data developed for Massachusetts and a statewide assessment of potential climate impacts, informed by expert analysis and stakeholder engagement. The prioritized list will be an important input to the 2023 State Hazard Mitigation and Climate Adaptation Plan.



Regional Overview

Geography and Demographics*

- 55 cities and towns
- 156,400 people
- 13% minority
- 25% low-income
- 1.2% households with limited English language proficiency

Resources and Assets

- 84,000 residential properties
- 8,500 miles of road
- 104,000 acres of agricultural land
- 1,018,000 acres of forest
- 1,900 miles of coldwater fisheries streams

**For definitions of these demographic terms, please see Volume II of this report.*

Regional Climate Outlook

2030	2050	2070	2090
NEAR TERM The summer mean temperature could increase by 3.6°F from the historical period (1950-2013), causing impacts to Berkshire dairy and crop agriculture.	**MID-CENTURY** The 1 percent annual chance river flood could be three times more likely to occur, increasing Housatonic and other river flood risk.	**MID-LATE CENTURY** There could be 63 fewer days below freezing, increasing the chance of ticks overwintering and contributing to increased Lyme disease risk.	**END OF CENTURY** The historical 10 percent annual chance daily rainfall event (2.8 to 4 inches) could occur five times more frequently.

Most Urgent Impacts by Sector for the Berkshires and Hilltowns Region

This region is characterized by rural landscapes, open space, and low population density. Impacts in all sectors of this region tend to stem from changes to the natural resources that are critical to the economy and way of life in the region. Below are the top two impacts per sector (additional impacts are listed for tied scores). The bookmark icons identify unique regional priorities, meaning for each sector, impacts that are not a top three most urgent impact statewide but are a top impact regionally.

Human

Increase in Vector Borne Diseases Incidence and Bacterial Infections, including West Nile Virus and Lyme disease due to more favorable conditions for ticks and mosquitoes.

Reduction in Food Safety and Security due to production and supply chain issues, as well as spoilage during power outages.

Infrastructure

Damage to Inland Buildings from heavy rainfall and overwhelmed drainage systems.

Reduction in Clean Water Supply, particularly for communities reliant on well water.

Damage to Electric Transmission and Utility Distribution Infrastructure associated with heat stress and extreme events.

Natural Environment

Freshwater Ecosystem Degradation due to warming waters, drought, and increased runoff.

Forest Health Degradation from warming temperatures, changing precipitation, extreme storms, and increasing pest occurrence.

Governance

Increase in Costs of Responding to Climate Migration, including planning for abrupt changes in local populations.

Increase in Demand for State and Municipal Government Services, including emergency response, food assistance, and state-sponsored health care.

Economy

Reduction in the Availability of Affordably Priced Housing from direct damage (e.g., flooding) and the scarcity caused by increased demand.

Damage to Tourist Attractions and Recreation Amenities, particularly those associated with distinct New England seasons.

Featured Adaptation Effort

Housatonic Stream Restoration for Regional Flood Resilience Project

Four communities (Lenox, Pittsfield, Stockbridge, and New Marlborough) conducted regional, community-wide assessments of approximately 400 culverts, and designed the replacement of three priority culverts. In partnership with the youth organization Greenagers, youth from Environmental Justice communities were trained and hired to conduct the assessments.

Photo: Town of Lenox

This Massachusetts Climate Change Assessment (Climate Assessment) evaluates a broad range of climate change risks to the Commonwealth, including impacts on human health, natural resources, and public and private assets. The Climate Assessment will serve as a core component of the 2023 update to the State Hazard Mitigation and Climate Adaptation Plan (SHMCAP), specifically concerning the detailed hazard risk assessment. The outputs of the Climate Assessment are designed to meet the requirements for State Hazard Mitigation Planning documents, and to directly inform and provide a risk prioritization focus to the Mitigation Strategy.

The Climate Assessment evaluates **impacts** from **climate stressors** (temperature, precipitation, sea level rise, etc.) and **climate hazards** (extreme heat, flooding, droughts, etc.) across five **sectors** in the state. The Assessment identifies statewide priority impacts that require near-term adaptation action as well as regional priorities for **seven regions** of the Commonwealth.

This report provides regional detail on the impacts of climate change in the Berkshires and Hilltowns region of Massachusetts. For more details on the methods used in this assessment, please refer to the Statewide Report.

Regional Context

Regional Character and Demographics

The Berkshires and Hilltowns make up the state's westernmost region, a mostly rural grouping of 55 cities and towns. The Berkshires and Hilltowns region has the smallest population among regions in this Assessment and is characterized by natural resources – it contains the Commonwealth's first state park (Mount Greylock, created in 1898) and was once named among The Nature Conservancy's twelve "Last Great Places" for its largely intact and unfragmented forests.[1] The region's largest population centers are Pittsfield, home to nearly 30 percent of the region's people, and North Adams. As in many parts of the state, healthcare and manufacturing are the largest industries, but tourism and agriculture also play a major role in the regional economy of the Berkshires and Hilltowns.[2]

The region's natural resources support much of this economic activity. The mountainous landscape provides huge recreational appeal across all seasons, with skiing and other winter sports providing a particularly significant tourist draw, fall drawing "leaf peepers," and summer supporting a varied cultural and outdoor recreation-related set of attractions. The forests, waters, and soils of the Berkshires and Hilltowns sustain a range of habitats and species in addition to supporting the region's agriculture and forestry economies. The region also serves as a cultural hub, with several notable museums, indoor and outdoor performance venues,

[1] Berkshire Regional Planning Commission. 2014. Conservation and Recreation: An Element of *Sustainable Berkshires*, Long-Range Plan for Berkshire County, Adopted 3.10.14. https://berkshireplanning.org/wp-content/uploads/program_documents/brpc_initiative/sustainable-berkshire-regional-plan-adopted/default/Sustainable_Berkshires-Conservation_and_Recreation-20140320.pdf

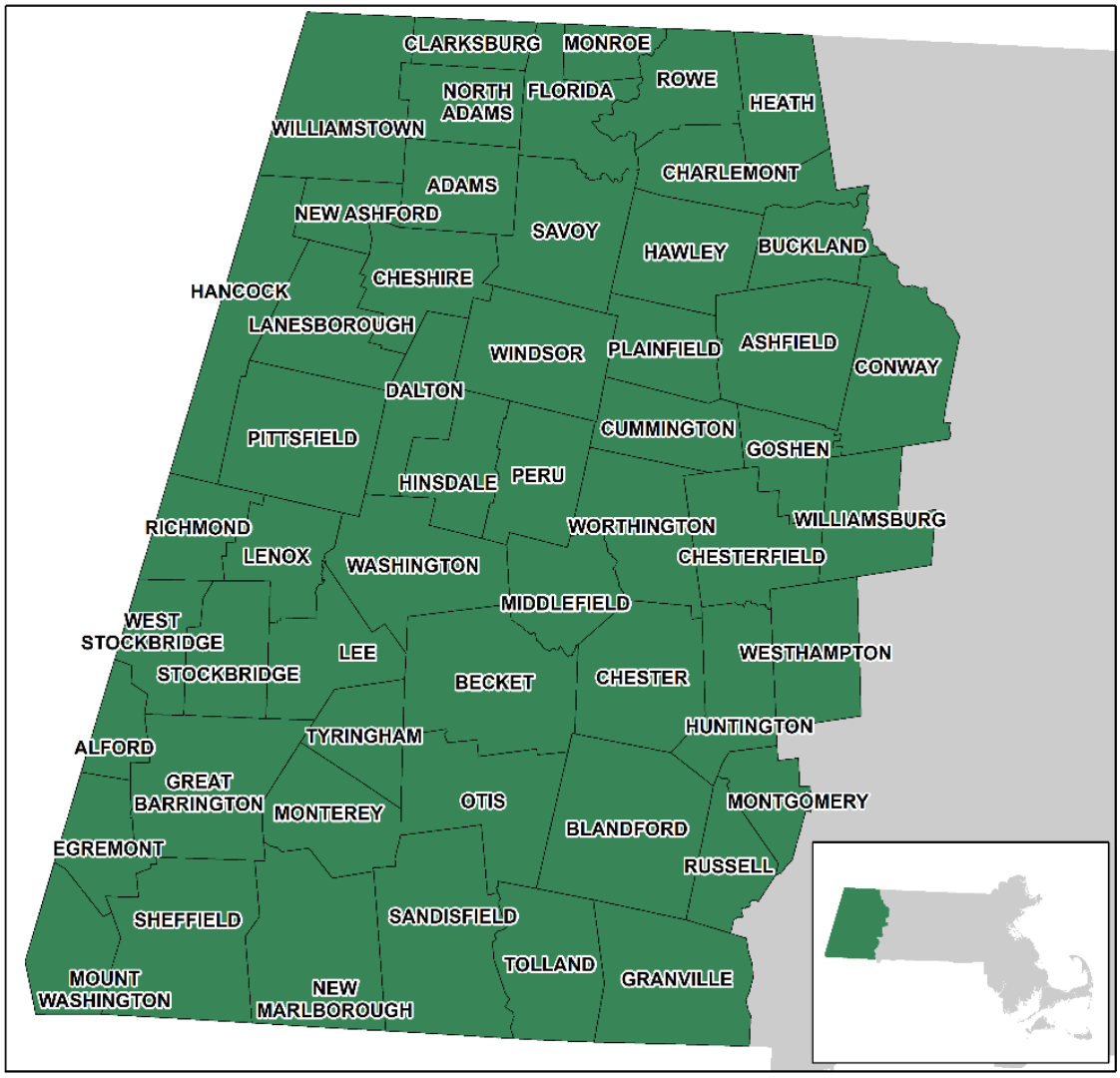
[2] Berkshire County Regional Employment Board. Regional Workforce Skills Planning Initiative Regional Blueprint. 2018. https://www.mass.gov/doc/berkshire-regional-workforce-skills-planning-initiative-regional-blueprint

trails, and historical sites that draw visitors from Massachusetts, surrounding states, and internationally.

The Berkshires and Hilltowns region boundary used for this assessment matches the Municipal Vulnerability Preparedness (MVP) program's Berkshires and Hilltowns region. Climate adaptation focus in the region is increasing, with all but a few communities having engaged in resilience and adaptation planning through the MVP program.

Cities and Towns in the Berkshires and Hilltowns Region

The MA Climate Change Assessment's Berkshires and Hilltowns region includes these 55 cities and towns.



Highlights of Future Climate Projections

The most important climate hazards for the region include temperature extremes, changes in precipitation patterns, and consequent changes in the patterns of river flows, all of which affect the agriculture and natural resources of the area and can have impacts on the rural beauty that drives seasonal tourism and characterizes this region. Summer season temperature changes in

particular may threaten the attractiveness of the region as both a haven from urban heat and an area with pristine recreational lakes (as elevated lake temperatures increase the risk of algal blooms). Some key findings of the climate change projections that may be important for this region over the 21st century include the following:

2030	2050	2070	2090
NEAR TERM	MID-CENTURY	MID-LATE CENTURY	END OF CENTURY
The summer mean temperature could increase by 3.6°F from the historical period (1950-2013), causing impacts to Berkshire dairy and crop agriculture.	The 1 percent annual chance river flood could be three times more likely to occur, increasing Housatonic and other river flood risk.	There could be 63 fewer days below freezing, increasing the chance of ticks overwintering and contributing to increased Lyme disease risk.	The historical 10 percent annual chance daily rainfall event (2.8 to 4 inches) could occur five times more frequently.

Urgent Impacts in the Berkshires and Hilltowns Region

Table 1 presents the two most urgent impacts per sector for the Berkshires and Hilltowns region (more than two impacts are listed in the case of ties). The sections that follow provide additional details on the regional rankings for each sector. For more details on all impact assessment methodologies, see Chapter 2 of Volume II, the Statewide Report.

Table 1. Most Urgent Impacts by Sector for the Berkshires and Hilltowns Region

Human Sector

- **Increase in Vector Borne Diseases Incidence and Bacterial Infections**, including West Nile Virus and Lyme disease due to more favorable conditions for ticks and mosquitoes.
- **Reduction in Food Safety and Security** due to production and supply chain issues, as well as spoilage during power outages.

Infrastructure Sector

- **Damage to Inland Buildings** from heavy rainfall and overwhelmed drainage systems.
- **Reduction in Clean Water Supply**, particularly for communities reliant on well water.
- **Damage to Electric Transmission and Utility Distribution** associated with heat stress and extreme events.

Natural Environment Sector

- **Freshwater Ecosystem Degradation** due to warming waters, drought, and increased runoff.
- **Forest Health Degradation** from warming temperatures, changing precipitation, extreme storms, and increasing pest occurrence.

Governance Sector

- **Increase in Costs of Responding to Climate Migration**, including planning for abrupt changes in local populations.
- **Increase in Demand for State and Municipal Government Services**, including emergency response, food assistance, and state-sponsored health care.

Economy Sector

- **Reduction in the Availability of Affordably Priced Housing** from direct damage (e.g., flooding) and the scarcity caused by increased demand.
- **Damage to Tourist Attractions and Recreation Amenities**, particularly those associated with distinct New England seasons.

Human Sector Impacts

The Berkshires and Hilltowns region faces unique challenges in the Health Sector given the unique population distribution and development patterns in the region. Increase in Vector Borne Diseases Incidence and Bacterial Infections and Reduction in Food Safety and Security both are projected to produce high magnitudes of consequence (extreme and major, respectively), with disproportionate exposure. Currently, approximately 100 cases of Lyme

Disease are reported annually in the Berkshires & Hilltowns region.[3] Forty additional annual cases of Lyme disease are projected to occur in the region in the near term (2030), with approximately 650 additional cases attributable to climate change by 2090. Minority and low-income populations are 14 percent to 16 percent more likely to be exposed to Lyme Disease within the Berkshires & Hilltowns region, compared to the rest of the regional population.[4] In Massachusetts, the impact of climate change on food security is typically associated with food access in rural regions such as the Berkshires and Hilltowns. Here, local agricultural supplies and local economies are more heavily dependent on local food production. Additionally, food insecurity may also be linked to vulnerability of food distribution networks to extreme event risks. The remaining impacts have relatively smaller expected consequences and are not projected to have disproportionate exposure in the region. Health Effects from Degraded Air Quality, though a top impact statewide, is not a priority concern in this region due to the local climate.

Table 2. Berkshires & Hilltowns Urgency Rankings for Human Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Increase in Vector Borne Diseases Incidence and Bacterial Infections	Increase in incidence of West Nile Virus, Lyme disease, and other diseases, and associated fatal and nonfatal outcomes, as a result of changes in temperature and an extended seasons for vectors and/or impact on bacterial loads.	Extreme	Disproportionate	Moderate
Reduction in Food Safety and Security	Temperature increases, spoilage, and power outages can lead to increased food contamina-tion. Changes in food production and supply chain disruption linked to climate change will worsen existing food insecurity.	Major	Disproportionate	Moderate
Health Effects from Aeroallergens and Mold	Impacts from extended pollen seasons, particularly on people with asthma or hay fever, and increases in exposure to mold spores associated with more frequent flood events and higher humidity conditions.	Moderate	Potential	Moderate
Increase in Mental Health Stressors	Negative effects of weather and climate change on mental health, including a broad range of impacts on overall well-being associated mostly with temperature stress.	Minimal	Potential	Moderate
Damage to Cultural Resources	Climate stressors can damage important cultural resources that hold special value to residents of the Commonwealth.	Minimal	Potential	Moderate

[3] Massachusetts Department of Public Health. 2014, Lyme Disease Surveillance in Massachusetts. Available at https://www.mass.gov/lists/tick-borne-disease-surveillance-summaries-and-data#lyme-disease-surveillance-data- Data averaged for 2010 to 2014 and transformed from county data to Climate Assessment region based on population distribution.

[4] Author's analysis using methods from Couper, L.I., MacDonald, A.J., and Mordecai, E.A. 2020. Impact of prior and projected climate change on U.S. Lyme disease incidence. Global Change Biology, 27(4), 738-754.

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Health Effects of Extreme Storms and Power Outages	Power outages and flooding, which could increase with more frequent extreme events, lead to a range of morbidity and sometimes fatal health outcomes and an increase in requests for emergency services.	Moderate	Limited	Moderate
Health and Cognitive Effects from Extreme Heat	Impacts of extreme heat episodes on health, learning, and workplace injuries – covers all health aspects of changes in frequency and severity of days with extreme temperatures.	Minimal	Limited	Moderate

Note: Health Effects from Degraded Air Quality and Emergency Service Response Delays and Evacuation Disruptions are not significant threats in this region.

Infrastructure Sector Impacts

Precipitation and hydrological changes are projected to cause the most urgent impacts to infrastructure in this region. The Berkshires and Hilltowns region has a high risk for inland flooding when measured as a percentage of the total structure value in the region. The region is also expected to have the largest absolute annual economic impact of inland flooding in the Commonwealth by 2030 ($4.7 million annually). These economic damages attributed to climate change could double by 2090.[5] Damage to Electric Transmission and Distribution Infrastructure is expected to increase over the century, with annual repair, capital, and operating cost increases due to climate change projected at $1.5 million by 2030 and $5.8 million by 2090.[6] Clean water supply is also a critical issue in the region, particularly as compared the rest of the Commonwealth, as many households and businesses rely on groundwater supply which may become more unreliable. Damages to roads could pose the highest magnitude of consequence if current adaptation actions are not continued.

Table 3. Berkshires & Hilltowns Urgency Rankings for Infrastructure Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Damage to Inland Buildings	Addresses the risk of flooding to inland structures from rainfall (pluvial flooding) when drainage systems are overwhelmed by large rainstorms and rivers (fluvial flooding).	Major	Disproportionate	Moderate
Reduction in Clean Water Supply	Addresses changes in water quantity and quality for water supplied for all human uses. Changes in precipitation patterns and saltwater intrusion can lead to impaired	Major	Potential	Moderate

[5] The results are based primarily on data from: Wobus, C.W., Porter, J., Lorie, M., Martinich, J., & Bash, R. (2021). Climate change, riverine flood risk and adaptation for the conterminous United States. Environmental Research Letters. doi: 10.1088/1748-9326/ac1bd7. Data on damage ratios by block group and integer degree were downloaded from: www.epa.gov/CIRA/social-vulnerability-report, see data supporting Appendix I.

[6] Fant, C., B. Boehlert, K. Strzepek, P. Larsen, A. White, S. Gulati, Y. Li, and J. Martinich (2020). Climate change impacts and costs to U.S. electricity transmission and distribution infrastructure. *Energy*, 195, 116899, doi:10.1016/j.energy.2020.116899. Available online at https://www.sciencedirect.com/science/article/pii/S0360544220300062

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
	surface and groundwater supply available for municipal, industrial, commercial, and agricultural uses.			
Damage to Electric Transmission and Utility Distribution Infrastructure	Costs to repair transmission infrastructure failure associated with heat stress and extreme events that directly affect the transmission and distribution system. Includes wired communication and information technology systems.	Major	Potential	Moderate
Loss of Energy Production and Resources	Changes in temperature increase electricity demand and reduce production efficiency, requiring changes in the overall network cost of meeting electric demand. Effects on solar energy production potentially subject to flooding are also considered.	Major	Limited	Moderate
Damage to Roads and Loss of Road Service	Damage to roads from extreme precipitation, flooding, and temperature increases the need for repair and maintenance, and indirect effects of increased vehicle operating costs from driving on roads in poor condition. Includes effects on bridges and culverts at road crossings.	Extreme	Limited	Minimal
Damage to Rails and Loss of Rail/Transit Service	Extreme temperature events reduce useful life of track and cause buckling events, which also lead to indirect impacts from delays that occur due to track buckling and repair. Also addressed are effects of storms and sea level rise on subway and commuter rail operation.	Minimal	Limited	Moderate
Loss of Urban Tree Cover	Urban trees are susceptible to invasive pests and high heat/drought conditions and provide many services including mitigating heat island effects, pollution removal, etc.	Insignificant	Potential	Minimal
Increased Risk of Dam Overtopping or Failure	Climate change could lead to more frequent overtopping of some, or all of the state dam safety program designated High or Significant Hazard dams, causing flooding of downstream areas.	Minimal	Limited	Minimal

Note: Damage to Coastal Buildings and Ports is not a significant threat in this region

Natural Environment Sector Impacts

Natural resources play an important role in this region in terms of the abundance of natural areas compared to the rest of the Commonwealth, and connection of natural resources to the economy through tourism and agriculture. The Berkshires and Hilltowns region is home to the most miles of coldwater fisheries streams of any region in the Commonwealth.[7] In a study of Massachusetts coldwater habitats, Ebersole et al. 2020 find that coldwater species occurrence

[7] GIS analysis of Coldwater Fisheries data from MassDEP, available at https://www.mass.gov/info-details/massgis-data-ma-wildlife-coldwater-fisheries-resources.

probability may decrease 42 to 77 percent by 2070.[8] Forests cover over one million acres in the region. Climate change threatens to degrade ecosystem service flows from forests through habitat transition (driven by changing temperature and precipitation regimes) and increased mortality from pests, pathogens, and invasive species as well as more extreme weather (e.g., ice and wind storms). Adaptation to these impacts in generally ongoing, however the scale of resources in the region requires significant attention to adequately address these risks.

Table 4. Berkshires & Hilltowns Urgency Rankings for Natural Environment Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Freshwater Ecosystem Degradation	Rising temperature and changing precipitation patterns will lead to a reduction in water quality and changes in water quantity, resulting in changes to habitat quality in rivers, streams, ponds, lakes and freshwater wetlands.	Extreme	Potential	Extreme
Forest Health Degradation	Warming temperatures, changing precipitation, increasing pest occurrence, more frequent and intense storms, and increased wildfire risk may cause a decline in forest health (e.g., biodiversity, biomass, resiliency) along with the loss of carbon sequestration and other ecosystem services. Impacts vary by forest type.	Extreme	Potential	Moderate
Shifting Distribution of Native and Invasive Species	Changing climatic conditions shift and eliminate suitable habitat for native species (flora and fauna), increase the risk of new species introductions, and increases competition from established invaders, potentially causing losses in native biodiversity and loss of culturally important species.	Major	Potential	Moderate
Soil Erosion	Increase in extreme precipitation results in increased erosion and loss of vegetation or changes in vegetation type, particularly along riverbanks but also in forests and in a number of landscapes	Major	Potential	Moderate

Note: Coastal Wetland Degradation, Marine Ecosystem Degradation, and Coastal Erosion are not significant impacts in this region.

Governance Sector Impacts

Climate impacts on governance are exacerbated in this region by the relatively small operating budgets of municipalities in the region. Regional cooperation will be important for facing the challenges of climate change. The region could face significant costs as receivers of climate migrants from other areas of the Commonwealth (particularly areas at risk of sea level rise) and beyond. Though it is difficult to confidently project future migration patterns, recent experiences during the height of the Covid-19 pandemic suggest the region could be a desirable

[8] Ebersole, J.L., Quiñones, R.M., Clements, S. and Letcher, B.H., 2020. Managing climate refugia for freshwater fishes under an expanding human footprint. Frontiers in Ecology and the Environment, 18(5), pp.271-280.

place for relocation. While new populations can bring benefits to receiving communities, the potential costs of climate migration include specialized housing provision, both short-term and medium-term; social services; increased educational costs to school systems; and pressure on existing public infrastructure related to potentially abrupt population increases. Increase in Demand for State and Municipal Government Services, even for the existing population, is another impact with projected major consequences, with the potential for disproportionate exposure. For this region there could be increased needs for MassHealth (connected to extreme heat impacts on health), food security support (which would expand the need for state-level SNAP programs), and emergency response as a result of climate change (particularly connected to impassable roads during inland flooding events). Many of these impacts can be expected to be concentrated among those residing in low-income block groups.

Table 5. Berkshires & Hilltowns Urgency Rankings for Governance Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Increase in Costs of Responding to Climate Migration	Costs and stresses to governments accommodating and/or preparing for forced and voluntary human migration of populations in response to climate threats or related economic pressures. Includes intra-state, inter-state, and international in- and out-migration, and is generally more abrupt than routine population changes in response to non-climate stressors (such as economic development or decline).	Major	Potential	Extreme
Increase in Demand for State and Municipal Government Services	Climate change serves as a threat multiplier, which can increase the need for expenditures to meet existing government service. Examples include capital, equipment, or operating costs for emergency response provision and state sponsored health programs.	Major	Potential	Moderate
Reduction in State and Municipal Revenues	State and municipal revenue streams impacted through property tax loss following structure damage of any type, from any hazard, and sales tax losses associated with business interruptions or effects on industrial activities.	Moderate	Potential	Moderate
Increase in Need for State and Municipal Policy Review and Adaptation Coordination	State agencies and municipalities may require additional full-time employees and specialized training to meet the challenges of climate change. Specifically, state and municipal staff will need capacity to provide adaptation planning support and to review and modify policies in response to changing conditions and uncertainty associated with climate change.	Moderate	Potential	Minimal
Damage to Inland State and Municipal	Risk to vulnerable structures and other property from flooding, extreme heat, and extreme storms. Includes damage repair costs and service losses during closures.	Minimal	Limited	Minimal

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Buildings and Land				

Note: Damage to Coastal State and Municipal Buildings and Land is not a significant impact in this region

Economy Sector Impacts

The current supply of affordably priced housing in the Berkshires and Hilltowns, already limited due to an influx of people during the pandemic, may be further strained by the need to house seasonal workers in the tourism and hospitality sector and by migratory pressures, especially among those who may now or in the future be moving away from climate risks (including wildfire, drought, coastal hazards, and extreme summer temperatures). Also, while there is less federally subsidized affordable housing in the region, this region has a relatively high potential inland flood risk to housing which is within the 25th percentile housing cost on the private market – the annual expected flood damages to this class of housing in the region could be $5 million in 2030 but could double to $10 million annually by 2090. The tourism industry is a key contributor to the Commonwealth's economy, and in particular, to the economy in the Berkshires and Hilltowns Region. According to the 2020 Massachusetts Office of Travel and Tourism (MOTT) Annual Report, in 2018 visitor expenditures in the Berkshires and Hilltowns region supported 4,200 jobs, generated $41 million in state ($26 million) and local ($15 million) tax revenue, and contributed $625 million in direct economic impacts.[9,10] The Berkshires and Hilltowns region has the highest tourism-related employment per capita of any region in the Commonwealth. The readily quantified losses to this industry in the Berkshires and Hilltowns are from loss of winter activities (although tourism and recreation in other seasons are also important to the region). The region is projected to lose about 60 percent of the winter sport days by 2050 (down to 17 days with downhill skiing conditions and eight days with snowmobiling and cross-country skiing conditions) and virtual all winter recreation days by 2090 (four downhill skiing days and two snowmobiling and cross-country skiing days remain).[11] At the same time, longer summer and shoulder seasons (i.e., spring and fall) could extend the high season for tourism for many destinations, although the timing of changing foliage colors and maple sugaring may become more unpredictable in the future, thus making it difficult to plan seasonal festivals other tourism draws. Beyond industry revenue losses and associated jobs, these effects will also impact residents who participate in these activities recreationally. Environmental health stressors may decrease participation across activities—for example,

[9] Massachusetts Office of Travel & Tourism. 2020. 2019 Annual Report. Available at: https://www.visitma.com/wp-content/uploads/2020/06/2020_Annual_Report.pdf.

[10] The 2021 annual report is also available however the more recent figures from 2020 reflect the disruptions to the tourism industry of the Covid-19 pandemic. In 2020, visitor expenditures supported over 100,000 jobs in 2020 and generated $879.9 million in state and local tax revenue. Figures are provided by county and converted to Climate Assessment regions by population.

[11] Wobus, C., Small, E.E., Hosterman, H., Mills, D., Stein, J., Rissing, M., Jones, R., Duckworth, M., Hall, R., Kolian, M. and Creason, J., 2017. Projected climate change impacts on skiing and snowmobiling: A case study of the United States. Global Environmental Change, 45, pp.1-14.

increased aeroallergens, threats of vector borne disease, decreased air quality due to wildfires, in addition to extreme heat days in the summer.

Table 6. Berkshires & Hilltowns Urgency Rankings for Economy Sector Impacts

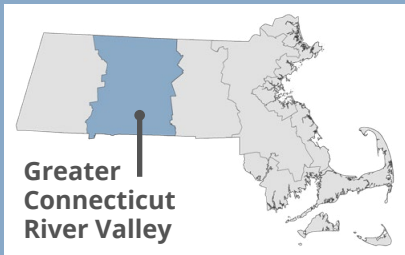
Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Reduction in the Availability of Affordably Priced Housing	An increase in demand for housing that is affordable and a decrease in supply worsens the scarcity of affordably priced housing. Demand for housing that is affordable can result if people are forced to relocate either due to direct damage to existing housing or because of climate-related economic pressures. The supply of affordably priced housing is reduced due to direct physical damage from climate impacts and potentially higher construction costs to increase resilience to threats from climate change.	Major	Disproportionate	Extreme
Damage to Tourist Attractions and Recreation Amenities	Changes to revenues in the tourism and recreation industry, particularly those associated with distinct New England seasons (e.g., winter recreation, foliage viewing), recreational fishing, beach recreation (i.e., reduction in beach width due to sea level rise and coastal erosion), and tourism related to vulnerable historical landmarks.	Major	Disproportionate	Moderate
Decrease in Agricultural Productivity	Reduction in crop yields for major agricultural products including field crops and tree products due to changing temperature and precipitation patterns, extreme weather, loss of pollinators, saltwater intrusion, and others.	Major	Potential	Moderate
Reduced Ability to Work	More frequent extreme heat days leads to lost wages and decreased productivity, as do increasing incidence of climate-induced health effects (e.g., asthma, allergies, vector borne disease, extreme heat). Weather-induced disruptions to transportation and ability to work may also lead to lost wages and worker productivity. Impacts are felt most by workers in outdoor industries, those who rely on public transportation, and those who care for others at home.	Minimal	Potential	Moderate
Economic Losses from Commercial Structure Damage and Business Interruptions	Reduction in economic outputs during closures resulting from flooding and storm damage to places of business, as well as reductions in economic output due to extreme weather shutdowns, utility and infrastructure disruptions, and climate-driven supply chains issues.	Minimal	Limited	Moderate

Note: Decrease in Marine Fisheries and Aquaculture Productivity is not a significant impact in this region.

Greater Connecticut River Valley Region Climate Impacts

The Commonwealth is already experiencing climate change impacts. The Greater Connecticut River Valley region is particularly vulnerable to climate hazards such as increasing temperatures, more extreme precipitation, and associated flooding. An understanding of the current and future impacts of climate change allows community decision-makers to best tailor adaptation plans to meet the specific challenges faced in this region. This report summarizes the highest urgency climate impacts across Human, Infrastructure, Natural Environment, Governance, and Economy sectors for the Greater Connecticut River Valley region.

The highest urgency impacts are based on a review of the latest climate data developed for Massachusetts and a statewide assessment of potential climate impacts, informed by expert analysis and stakeholder engagement. The prioritized list will be an important input to the 2023 State Hazard Mitigation and Climate Adaptation Plan.



Regional Overview

Geography and Demographics*

- 65 cities and towns
- 788,200 people
- 33% minority
- 31% low-income
- 5% households with limited English language proficiency

Resources and Assets

- 267,000 residential properties
- 15,900 miles of road
- 129,500 acres of agricultural land
- 1,187,000 acres of forest
- 1,600 miles of coldwater fisheries streams

**For definitions of these demographic terms, please see Volume II of this report.*

Regional Climate Outlook

2030	2050	2070	2090
NEAR TERM The summer mean temperature could increase by 3.6°F from the historical period (1950-2013), increasing urban heat stress and reducing local crop yields.	**MID-CENTURY** The 1 percent annual chance river flood could be three times more likely to occur, increasing Connecticut River and other area flood risk.	**MID-LATE CENTURY** There could be 65 fewer days below freezing, increasing the chance of ticks overwintering and reducing winter recreation opportunities.	**END OF CENTURY** The historical 10 percent annual chance daily rainfall event (2.6 to 4 inches) could occur four times more frequently.

Most Urgent Impacts by Sector for the Greater Connecticut River Valley Region

Centered around the Connecticut River, this region includes rural towns and urban centers. Many of the most urgent climate impacts are already large concerns in the region (e.g., food security, agriculture, and housing). Below are the top two impacts per sector (three listed for tied scores). The bookmark icons identify unique regional priorities, meaning for each sector, impacts that are not a top three most urgent impact statewide but are a top two impact regionally.

Human

Reduction in Food Safety and Security due to production and supply chain issues, as well as spoilage during power outages.

Health Effects of Extreme Storms and Power Outages, including from injuries, food safety, and medical device failure.

Infrastructure

Damage to Inland Buildings from heavy rainfall and overwhelmed drainage systems.

Damage to Electric Transmission and Utility Distribution Infrastructure associated with heat stress and extreme events.

Natural Environment

Shifting Distribution of Native and Invasive Species as changing climate conditions favor certain species.

Freshwater Ecosystem Degradation due to warming waters, drought, and increased runoff.

Forest Health Degradation from warming temperatures, changing precipitation, extreme storms, and increasing pest occurrence.

Governance

Increase in Costs of Responding to Climate Migration, including planning for abrupt increases in local populations.

Reduction in State and Municipal Revenues, including a reduced property tax base due to inland flood risk.

Economy

Decrease in Agricultural Productivity as crop yields are impacted by precipitation patterns, extreme weather, pests, and other climate factors.

Reduction in the Availability of Affordably Priced Housing from direct damage (e.g., flooding) and the scarcity caused by increased demand.

Featured Adaptation Effort

Pine Grove Golf Course Site Restoration

The City of Northampton, in partnership with MassAudubon, restored 105 acres of land formerly used as a golf course. The project included permanent protection of the land, removal of drainage infrastructure, and elimination of multiple stream crossings. Ten acres of previously drained wetlands were restored, and greenways were reverted to early successional forests.

This Massachusetts Climate Change Assessment (Climate Assessment) evaluates a broad range of climate change risks to the Commonwealth, including impacts on human health, natural resources, and public and private assets. The Climate Assessment will serve as a core component of the 2023 update to the State Hazard Mitigation and Climate Adaptation Plan (SHMCAP), specifically concerning the detailed hazard risk assessment. The outputs of the Climate Assessment are designed to meet the requirements for State Hazard Mitigation Planning documents, and to directly inform and provide a risk prioritization focus to the Mitigation Strategy.

The Climate Assessment evaluates **impacts** from **climate stressors** (temperature, precipitation, sea level rise, etc.) and **climate hazards** (extreme heat, flooding, droughts, etc.) across five **sectors** in the state. The Assessment identifies statewide priority impacts that require near-term adaptation action as well as regional priorities for **seven regions** of the Commonwealth.

This report provides regional detail on the impacts of climate change in the Greater Connecticut River Valley region of Massachusetts. For more details on the methods used in this assessment, please refer to the Statewide Report.

Regional Context

Regional Character and Demographics

The Greater Connecticut River Valley region is primarily rural, though it does feature the state's third largest city, Springfield, and surrounding cities, as well as networks of larger villages. The region accounts for about 11 percent of the state's population but includes nearly 21 percent of its low-income block groups. Overall, more than 52 percent of the Greater Connecticut River Valley's block groups receive EEA's environmental justice designation, making the region one of only two where more than half the block groups are considered socially vulnerable.[12] The regional economy largely reflects the statewide economy, with healthcare, finance, insurance, and professional services playing large roles. Agriculture is also a major player in the region for employment and economic output.[13]

The Greater Connecticut River Valley contains some of the state's most important freshwater resources. In addition to the Connecticut and its tributaries, the region is home to the Quabbin Reservoir, which provides clean water for municipal and industrial uses across the Commonwealth, though to relatively few communities within the Greater Connecticut River Valley region. Other local drinking water sources include the Tighe-Carmody Reservoir, Ashley Reservoir, Roberts Reservoir, as well as important groundwater resources. Terrestrial natural resources are also important in the region, with fertile soils supporting the forests and agricultural lands that cover much of the central and northern part of the Greater Connecticut River Valley.

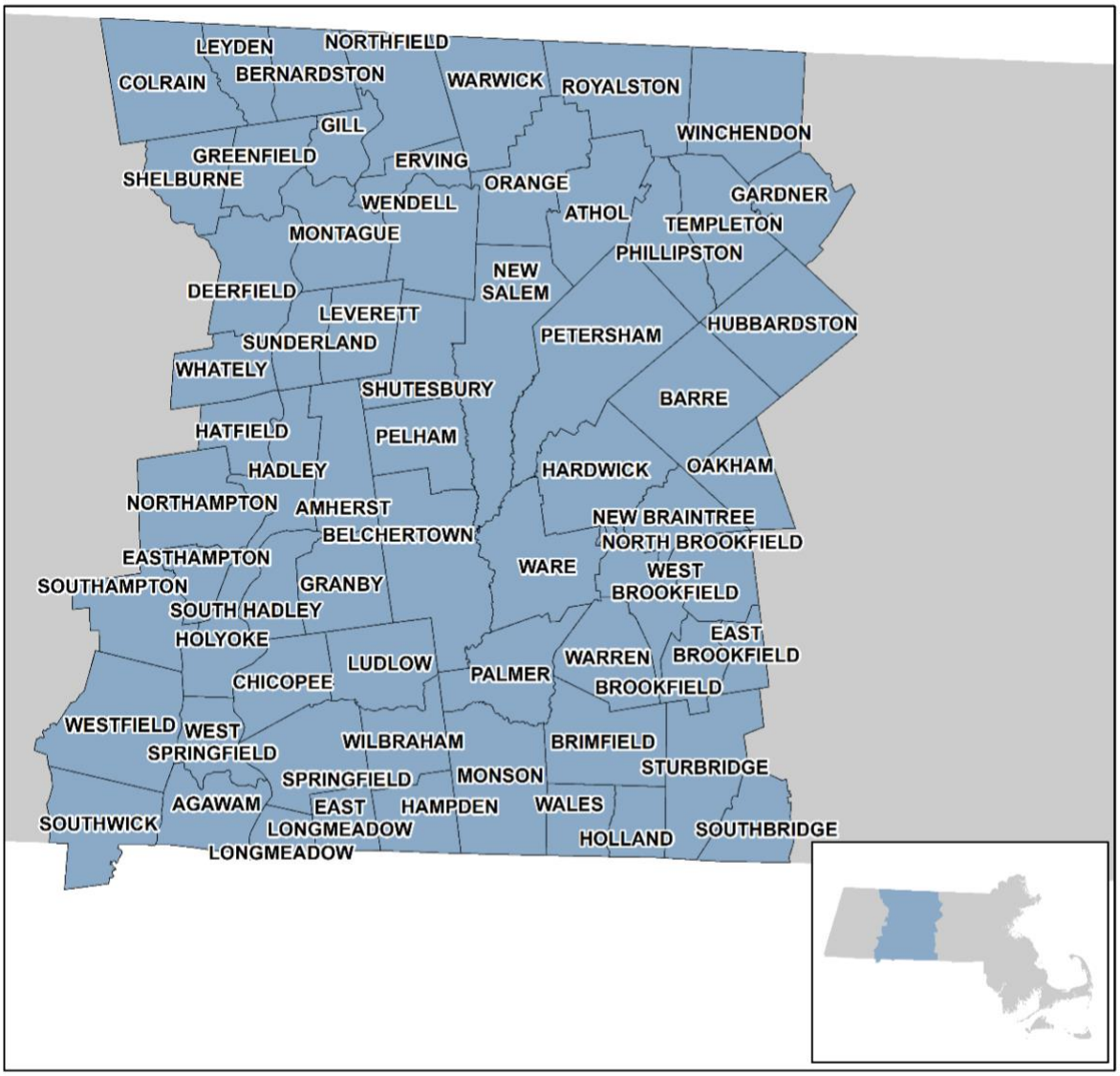
[12] The other is Boston Harbor, with nearly two thirds of block groups being EJ-designated by EEA.

[13] Regional Employment Boards of Franklin & Hampshire Counties and Hampden County. Pioneer Valley Labor Market Blueprint. https://www.mass.gov/doc/pioneer-valley-regional-workforce-skills-planning-initiative-regional-blueprint/download

The boundary used for this assessment matches the Municipal Vulnerability Preparedness (MVP) program's Greater Connecticut River Valley region. Climate adaptation work is progressing in the region, but a few communities still have yet to engage in climate resilience planning through the MVP program.

Cities and Towns in the Greater Connecticut River Valley Region

The MA Climate Change Assessment's Greater Connecticut River Valley region includes these 65 cities and towns.



Highlights of Future Climate Projections

The most important climate hazards for the region include temperature extremes, changes in precipitation patterns, and consequent changes in the patterns of river flows, particularly in the Connecticut River and its network of tributaries. Each of these affects both the urban areas in the southern portion of the region and the agriculture and natural resources that characterize

the northern, more rural areas. Some key findings of the climate change projections that may be important for this region over the 21st century include the following:

2030	2050	2070	2090
NEAR TERM	MID-CENTURY	MID-LATE CENTURY	END OF CENTURY
The summer mean temperature could increase by 3.6°F from the historical period (1950-2013), increasing urban heat stress and reducing local crop yields.	The 1 percent annual chance river flood could be three times more likely to occur, increasing Connecticut River and other area flood risk.	There could be 65 fewer days below freezing, increasing the chance of ticks overwintering and reducing winter recreation opportunities.	The historical 10 percent annual chance daily rainfall event (2.6 to 4 inches) could occur four times more frequently.

Urgent Impacts in the Greater Connecticut River Valley Region

Table 7 presents the two most urgent impacts per sector for the Greater Connecticut River Valley region (more than two impacts are listed in the case of ties). The sections that follow provide additional details on the regional rankings for each sector. For more details on all impact assessment methodologies, see Chapter 2 of Volume II, the Statewide Report.

Table 7. Two Most Urgent Impacts by Sector for the Greater Connecticut River Valley Region

Human Sector

- **Reduction in Food Safety and Security** due to production and supply chain issues, as well as spoilage during power outages.
- **Health Effects of Extreme Storms and Power Outages**, including from injuries, food safety, and medical device failure.

Infrastructure Sector

- **Damage to Inland Buildings** from heavy rainfall and overwhelmed drainage systems.
- **Damage to Electric Transmission and Utility Distribution Infrastructure** associated with heat stress and extreme events.

Natural Environment Sector

- **Shifting Distribution of Native and Invasive Species** as changing climate conditions favor certain species.
- **Freshwater Ecosystem Degradation** due to warming waters, drought, and increased runoff.
- **Forest Health Degradation** from warming temperatures, changing precipitation, extreme storms, and increasing pest occurrence.

Governance Sector

- **Increase in Costs of Responding to Climate Migration**, including planning for abrupt changes in local populations.
- **Reduction in State and Municipal Revenues**, including a reduced property tax base due to inland flood risk.

Economy Sector

- **Decrease in Agricultural Productivity** as crop yields are impacted by precipitation patterns, extreme weather, pests, and other climate factors**.**
- **Reduction in the Availability of Affordably Priced Housing** from direct damage (e.g., flooding) and the scarcity caused by increased demand.

Human Sector Impacts

Reduction in Food Safety and Security and Health Effects of Extreme Storms and Power Outages are the most urgent impacts in the Greater Connecticut River Valley region. In Massachusetts, the impact of climate change on food security is typically associated with food access in rural regions, which makes the Greater Connecticut River Valley region vulnerable. Here, local agricultural supplies and economies are more heavily dependent on local food production. The region accounts for 57 percent of statewide agricultural productivity and could see key commodity crop yields decline by eight percent by 2030 and 20 percent by 2070.[14] Additionally, food insecurity may also be linked to vulnerability of food distribution networks to extreme event risks. Food safety concerns like spoilage and bacterial contamination are also associated with high temperature events and risk of power outages. One of the largest food distribution centers in Massachusetts is located in Springfield and supplies consumers throughout the Commonwealth. It is located within the 100-year floodplain of the Connecticut River, where it may be vulnerable to flooding, potentially leading to interruption of food supply chains.

These flood risks also directly threaten human health through increased risk of injury and disease both during and after the event. Currently, extreme weather incidents account for an estimated 4 cases of carbon monoxide poisoning and 47 medical incidents annually in the region. One additional case of carbon monoxide poisoning and 10 additional medical incidents are expected by 2070,[15] making this impact minimal. However, the currently available data limit comprehensive quantification of these impacts—the actual estimates are likely to be much higher, in part because this region is expected to among the hardest hit by increases in inland flooding risk that could result from climate change. These impacts are also disproportionately distributed in the region. Linguistically isolated populations and minority populations are respectively 20 percent and 21 percent more likely to experience health effects of extreme storms and power outages in the region compared to the rest of the population. This disproportionality comparatively elevates the urgency of these impacts when compared with others in the Human sector.

[14] See Statewide report for more details. Estimates derived from application of USEPA. 2017. Multi-Model Framework for Quantitative Sectoral Impacts Analysis: A Technical Report for the Fourth National Climate Assessment. U.S. Environmental Protection Agency, EPA 430-R-17-001. and Beach, R., Y. C, A. Thomsom, X. Zhang, R. Jones, B. McCarl, A. Crimmins, J. Martinich, J. Cole, S. Ohrel, B. DeAngelo, J. McFarland, K. Strzepek, and B. Boehlert. 2015. Climate change impacts on US agriculture and forestry: benefits of global climate stabilization. Environmental Research Letters. doi:10.1088/1748-9326/10/9/095004.

[15] See Statewide report for more details. Estimates derived from application of Kintziger, K.W., Jagger, M.A., Conlon, K.C., Bush, K.F., Haggerty, B., Morano, L.H., Lane, K., Roach, M., Thie, L. and Uejio, C.K., 2017. Technical documentation on exposure-response functions for climate-sensitive health outcomes. Available at https://www.cdc.gov/climateandhealth/docs/ExposureResponseFunctions_508.pdf and Kintziger, K.W., Odoi, E.W., Jagger, M.A. 2019. Impacts of Climate Change & Extreme Weather on Injury: A Primer for Investigation Focusing on Hurricane-Related Impacts. Presented at the January 8, 2019 annual meeting of the American Meteorological Association, as part of Themed Joint Session 15 – Hurricanes and Health: When Will We Stop "Learning Lessons" and Start Building Smarter? Abstract and recorded presentation available at: https://ams.confex.com/ams/2019Annual/webprogram/Paper354540.html; presentation text obtained from the authors.

Table 8. Greater Connecticut River Valley Urgency Rankings for Human Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Reduction in Food Safety and Security	Temperature increases, spoilage, and power outages can lead to increased food contamination. Changes in food production and supply chain disruption linked to climate change will worsen existing food insecurity.	Major	Disproportionate	Moderate
Health Effects of Extreme Storms and Power Outages	Power outages and flooding, which could increase with more frequent extreme events, lead to a range of morbidity and sometimes fatal health outcomes and an increase in requests for emergency services.	Moderate	Disproportionate	Moderate
Health and Cognitive Effects from Extreme Heat	Impacts of extreme heat episodes on health, learning, and workplace injuries - covers all health aspects of changes in frequency and severity of days with extreme temperatures.	Moderate	Potential	Moderate
Increase in Mental Health Stressors	Negative effects of weather and climate change on mental health, including a broad range of impacts on overall well-being associated mostly with temperature stress.	Moderate	Potential	Moderate
Damage to Cultural Resources	Climate stressors can damage important cultural resources that hold special value to residents of the Commonwealth.	Moderate	Potential	Moderate
Health Effects from Aeroallergens and Mold	Impacts from extended pollen seasons, particularly on people with asthma or hay fever, and increases in exposure to mold spores associated with more frequent flood events and higher humidity conditions.	Moderate	Potential	Moderate
Increase in Vector Borne Diseases Incidence and Bacterial Infections	Increase in incidence of West Nile Virus, Lyme disease, and other diseases, and associated fatal and nonfatal outcomes, as a result of changes in temperature and an extended seasons for vectors and/or impact on bacterial loads.	Major	Limited	Moderate
Emergency Service Response Delays and Evacuation Disruptions	Extreme storms cause delays in response time, potentially leading to loss of life. Extreme coastal storm surge events and inland flooding could flood evacuation routes, trapping residents, leading to increased loss of life and injuries.	Moderate	Limited	Moderate
Health Effects from Degraded Air Quality	Impacts of climate-induced changes in ambient and indoor air quality on health (e.g., premature loss of life, health care costs, missed school). Focused on changes from the direct impact of climate on particulate matter and ozone air quality, and the resulting health effects associated with these pollutants.	Minimal	Limited	Minimal

Infrastructure Sector Impacts

The region's largest Infrastructure sector vulnerabilities align with key statewide impacts, with Damage to Inland Buildings and Damage to Electric Transmission and Distribution Infrastructure representing the most urgent impacts. The Greater Connecticut River Valley region has a high risk for inland flooding when measured as a percentage of the total structure value in the region, although this risk is widely differentiated across the region. The region is also expected to have the largest absolute annual economic impact of inland flooding in the Commonwealth by 2030, with $12 million in added annual costs. These economic damages attributed to climate change could double by 2090 to $24 million despite the finding that some more sparsely populated portions of the eastern portion of the region could see a decline in flood risk.[16] These risks are particularly disproportionate in the region—language isolated populations are exposed to a 3.5 times higher risk (350 percent higher) than other populations in the region, and populations in block groups designated as low income or minority are exposed to 26 percent and 30 percent higher risk of inland flooding than other populations in the region. Springfield and other neighboring communities (e.g., Holyoke, Chicopee) have invested in flood control, but adaptation efforts, particularly those aimed at residential properties, are currently limited across much of the region.

A range of climate stressors including extreme temperature, extreme storms, lightning, vegetation growth, wildfire activity, and coastal flooding threaten transmission and distribution lines, poles/towers, and transformers, making Damage to Electric Transmission and Distribution Infrastructure another key impact in the region. Added annual repair costs are projected to exceed $6 million by 2030 and reach nearly $23 million by 2090.[17] Loss of Urban Tree Cover is also projected to be a significant impact because low canopy coverage and high surface temperatures in densely-populated, developed areas (such as Chicopee and Springfield) will diminish ecosystem services (e.g. heat island mitigation and pollution removal) provided by canopy cover.

[16] These results are based primarily on data from Wobus, C.W., Porter, J., Lorie, M., Martinich, J., & Bash, R. (2021). Climate change, riverine flood risk and adaptation for the conterminous United States. Environmental Research Letters. doi: 10.1088/1748-9326/ac1bd7. Data on damage ratios by block group and integer degree were downloaded from: www.epa.gov/CIRA/social-vulnerability-report, see data supporting Appendix I.

[17] See Statewide report for more details. Estimates derived from application of Fant, C., Boehlert, B., Strzepek, K., Larsen, P., White, A., Gulati, S., Li, Y., & Martinich, J. (2020). Climate change impacts and costs to U.S. electricity transmission and distribution infrastructure. Energy, 195. Doi:10.1016/j.energy.2020.116899

Table 9. Greater Connecticut River Valley Region Urgency Rankings for Infrastructure Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Damage to Inland Buildings	Addresses the risk of flooding to inland structures from rainfall (pluvial flooding) when drainage systems are overwhelmed by large rainstorms and rivers (fluvial flooding).	Major	Disproportionate	Moderate
Damage to Electric Transmission and Utility Distribution Infrastructure	Costs to repair transmission infrastructure failure associated with heat stress and extreme events that directly affect the transmission and distribution system. Includes wired communication and information technology systems.	Major	Potential	Extreme
Loss of Urban Tree Cover	Urban trees are susceptible to invasive pests and high heat/drought conditions and provide many services including mitigating heat island effects, pollution removal, etc.	Moderate	Disproportionate	Minimal
Reduction in Clean Water Supply	Addresses changes in water quantity and quality for water supplied for all human uses. Changes in precipitation patterns can lead to impaired surface and groundwater supply available for municipal, industrial, commercial, and agricultural uses.	Major	Potential	Minimal
Damage to Rails and Loss of Rail/Transit Service	Extreme temperature events reduce useful life of track and cause buckling events, which also lead to indirect impacts from delays that occur due to track buckling and repair. Also addressed are effects of storms and sea level rise on subway and commuter rail operation.	Minimal	Potential	Moderate
Damage to Roads and Loss of Road Service	Damage to roads from extreme precipitation, flooding, and temperature increases the need for repair and maintenance, and indirect effects of increased vehicle operating costs from driving on roads in poor condition. Includes effects on bridges and culverts at road crossings.	Major	Limited	Minimal
Increased Risk of Dam Overtopping or Failure	Climate change could lead to more frequent overtopping of some, or all of the state dam safety program designated High or Significant Hazard dams, causing flooding of downstream areas.	Moderate	Limited	Minimal
Loss of Energy Production and Resources	Changes in temperature increase electricity demand and reduce production efficiency, requiring changes in the overall network cost of meeting electric demand. Effects on solar energy production potentially subject to flooding are also considered.	Moderate	Limited	Minimal

Note: Damage to Coastal Buildings and Ports is not a significant impact in this region.

Natural Environment Sector Impacts

The region's natural resources are expected to face significant pressure from climate change. The most urgent Natural Environment sector risks in the Great Connecticut River Valley are Shifting Distribution of Native and Invasive Species, Freshwater Ecosystem Degradation, and Forest Health Degradation. The three are closely related—climate change will alter existing biogeochemical cycles that support viable forest and freshwater habitats for native species to thrive and may consequently make it viable for invasive flora and fauna to thrive. Changes to temperature and precipitation regimes will shift growing seasons and impact nutrient availability, forcing forest ecosystems to transition and potentially diminishing the ecosystem services they provide. Statewide, a third of tree species are classified by the U.S. Forest Service as having low capacity for adapting to projected climate changes.[18] Changing flow patterns of waterways due to seasonal shifts, increased nutrient loading and harmful algal bloom growth, and increased contaminant concentrations during drought conditions threaten freshwater ecosystems. All of these ecosystem impacts could shift the competitive balance of native and invasive species, and extreme weather events could make ecosystems more vulnerable to pests and disease, weakening the ability of native flora and fauna to adapt to a new climate.[19]

Table 10. Greater Connecticut River Valley Urgency Rankings for Natural Environment Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Shifting Distribution of Native and Invasive Species	Changing climatic conditions shift and eliminate suitable habitat for native species (flora and fauna), increase the risk of new species introductions, and increases competition from established invaders, potentially causing losses in native biodiversity and loss of culturally important species.	Major	Potential	Extreme
Freshwater Ecosystem Degradation	Rising temperature and changing precipitation patterns will lead to a reduction in water quality and changes in water quantity, resulting in changes to habitat quality in rivers, streams, ponds, lakes, and freshwater wetlands.	Extreme	Potential	Moderate
Forest Health Degradation	Warming temperatures, changing precipitation, increasing pest occurrence, more frequent and intense storms, and increased wildfire risk may cause a decline in forest health (e.g., biodiversity, biomass, resiliency) along with the loss of carbon sequestration and other ecosystem services. Impacts vary by forest type.	Extreme	Potential	Moderate

[18] See Statewide report for more details. Estimates derived from application of US Forest Service Tree Atlas for Massachusetts: https://www.fs.usda.gov/nrs/atlas/combined/resources/summaries/states/Massachusetts.pdf and https://www.fs.usda.gov/nrs/atlas/combined/resources/summaries/states/

[19] Massachusetts Division of Fisheries & Wildlife (November 2016). Massachusetts State Wildlife Action Plan. https://www.mass.gov/service-details/state-wildlife-action-plan-swap

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Soil Erosion	Increase in extreme precipitation results in increased erosion and loss of vegetation or changes in vegetation type, particularly along riverbanks but also in forests and in a number of landscapes.	Major	Potential	Moderate

Note: Coastal Wetland Degradation, Marine Ecosystem Degradation, and Coastal Erosion are not significant impacts in this region.

Governance Sector Impacts

The Greater Connecticut River Valley's key Governance sector impacts are aligned with the most urgent statewide impacts: Increase in Costs of Responding to Climate Migration, Increase in Demand for State and Municipal Government Services, and Reduction in State and Municipal Revenues. Climate migration remains an emerging risk for Massachusetts, but there is direct experience with this impact in the region. Most notably, in 2017 and 2018, Holyoke—the Massachusetts city with the highest concentration of people of Puerto Rican descent in the contiguous U.S.—welcomed 142 Puerto Rican households permanently displaced and hundreds more temporarily displaced by Hurricane Maria.[20] In-state migration could also impact the region. Hauer et al. (2020) predict that Massachusetts is home to anywhere between 300 to 500 thousand individuals vulnerable to displacement due to sea level rising, either because they reside in low elevation coastal zones or in the 100-year projected floodplain.[21] Hauer reports that most American households displaced due to environmental phenomena migrate to nearby urban job-growth centers. Within Massachusetts, this outcome may be observed as a growth of small cities in the Greater Connecticut River Valley region.

Climate migration and other threats are expected to increase demand for government services. While new populations can bring benefits to receiving communities, the potential costs of climate migration include specialized housing provision, both short-term and medium-term; social services; increased educational costs to school systems; and pressure on existing public infrastructure related to potentially abrupt population increases. The need to increase expenditures to maintain the current level of governmental services represents a potentially important stressor for the local governments of the Greater Connecticut River Valley region. There could be increased needs for, MassHealth (connected to extreme heat impacts on health), food security support (which would expand the need for state-level SNAP programs), and emergency response resulting from climate change (particularly connected to impassable roads during inland flooding events). Many of these impacts are expected to be concentrated among those residing in low-income block groups.

[20] Carlos Vargas Ramos and Charles R. Venator-Santiago, 2019. Anticipated Vulnerabilities: Displacement and Migration in the Age of Climate Change - Holyoke's Response to Hurricane Maria for Massachusetts' Municipal Vulnerability Program. September 2019, https://storage.googleapis.com/proudcity/holyokema/uploads/2020/08/HolyokeStudy_MVP_13May2020_FinalRevision.pdf

[21] Hauer, M.E., Fussell, E., Mueller, V. et al (2020). Sea-level rise and human migration. Nat Rev Earth Environ 1, 28–39. https://doi.org/10.1038/s43017-019-0002-9

Table 11. Greater Connecticut River Valley Urgency Rankings for Governance Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Increase in Costs of Responding to Climate Migration	Costs and stresses to governments accommodating and/or preparing for forced and voluntary human migration of populations in response to climate threats or related economic pressures. Includes intra-state, inter-state, and international in- and out-migration, and is generally more abrupt than routine population changes in response to non-climate stressors (such as economic development or decline).	Major	Potential	Extreme
Reduction in State and Municipal Revenues	State and municipal revenue streams impacted through property tax loss following structure damage of any type, from any hazard, and sales tax losses associated with business interruptions or effects on industrial activities.	Moderate	Disproportionate	Moderate
Increase in Demand for State and Municipal Government Services	Climate change serves as a threat multiplier, which can increase the need for expenditures to meet existing government service. Examples include capital, equipment, or operating costs for emergency response provision and state sponsored health programs.	Major	Potential	Moderate
Increase in Need for State and Municipal Policy Review and Adaptation Coordination	State agencies and municipalities may require additional full-time employees and specialized training to meet the challenges of climate change. Specifically, state and municipal staff will need capacity to provide adaptation planning support and to review and modify policies in response to changing conditions and uncertainty associated with climate change.	Moderate	Potential	Minimal
Damage to Inland State and Municipal Buildings and Land	Risk to vulnerable state and municipal owned structures and other property from flooding, extreme heat, and extreme storms. Includes damage repair costs and service losses during closures.	Minimal	Limited	Minimal

Note: Damage to Coastal State and Municipal Buildings and Land is not a significant impact in the region.

Economy Sector Impacts

Decrease in Agricultural Productivity and Reduction in the Availability of Affordably Priced Housing are the most urgent impacts in the Economy sector for the region. The Greater Connecticut River Valley is home to the most farmland out of any region in the Commonwealth at 130,000 acres. Farming and agricultural revenues are important parts of the economy and identity of the region. Temperature and precipitation pattern changes may make it difficult to continue the cultivation of crops historically grown in the area while creating the opportunity to transition toward new crops. Such a transition, however, comes with associated challenges of marketing and lack of existing production and processing infrastructure. Lost production value

for corn, hay, potatoes in the region is projected to reach $1.6 million annual by 2030, $2.7 million by 2050 and $3.7 million by 2090, relative to $21 million in current production for these crops.[22,23] Pressures such as loss of pollinators, extreme storms, and invasive species and pests introduce further uncertainty into the agriculture industry, which is already facing economic pressures.

An increase in demand for housing and a decrease in supply are expected to negatively impact housing affordability. Relocation due to direct damage to existing housing or climate-related economic pressures drives increasing demand. Direct physical damage from climate impacts and higher construction costs needed to increase climate resilience may limit the availability of affordably priced housing. This region has a high potential inland flood risk to housing which is within the 25th percentile housing cost on the private market—the annual expected flood damages to this class of housing in the region could be $13 million by 2030 and could more than double to $29 million by 2090.[24] Both demand and supply effects raise rental and ownership prices, which can effectively limit options for affordably priced housing, particularly for low-income populations. Reduced Ability to Work, a key impact at the state level, is also projected to be important in this region, with annual lost hours per high-risk worker due to climate conditions reaching 114 by end of century.[25]

Table 12. Greater Connecticut River Valley Urgency Rankings for Economy Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Decrease in Agricultural Productivity	Reduction in crop yields for major agricultural products including field crops and tree products due to changing temperature and precipitation patterns, extreme weather, loss of pollinators, saltwater intrusion, and others.	Extreme	Potential	Extreme

[22] Results also include soybean production though baseline annual soybean production is less than $25,000 statewide.

[23] See Statewide report for more details. Estimates derived from application of USEPA. 2017. Multi-Model Framework for Quantitative Sectoral Impacts Analysis: A Technical Report for the Fourth National Climate Assessment. U.S. Environmental Protection Agency, EPA 430-R-17-001. and Beach, R., Y. C, A. Thomsom, X. Zhang, R. Jones, B. McCarl, A. Crimmins, J. Martinich, J. Cole, S. Ohrel, B. DeAngelo, J. McFarland, K. Strzepek, and B. Boehlert. 2015. Climate change impacts on US agriculture and forestry: benefits of global climate stabilization. Environmental Research Letters. doi:10.1088/1748-9326/10/9/095004.

[24] See Statewide report for more details. Estimates based on ACS property and structure value, U.S. EPA data at www.epa.gov/CIRA, and Project Team analysis.

[25] See Statewide report for more details. Estimates derived from application of Neidell, M., Graff Zivin, J., Sheahan, M., Willwerth, J., Fant, C., Sarofim, M. and Martinich, J., 2021. Temperature and work: Time allocated to work under varying climate and labor market conditions. PloS one, 16(8), p.e0254224.

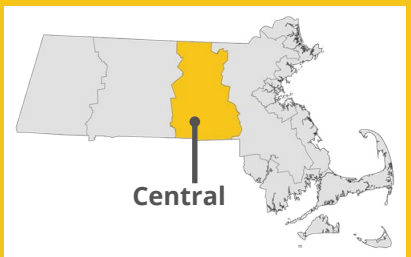
Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Reduction in the Availability of Affordably Priced Housing	An increase in demand for housing that is affordable and a decrease in supply worsens the scarcity of affordably priced housing. Demand for housing that is affordable can result if people are forced to relocate either due to direct damage to existing housing or because of climate-related economic pressures. The supply of affordably priced housing is reduced due to direct physical damage from climate impacts and potentially higher construction costs to increase resilience to threats from climate change.	Major	Disproportionate	Moderate
Reduced Ability to Work	More frequent extreme heat days leads to lost wages and decreased productivity, as do increasing incidence of climate-induced health effects (e.g., asthma, allergies, vector borne disease, extreme heat). Weather-induced disruptions to transportation and ability to work may also lead to lost wages and worker productivity.	Extreme	Potential	Moderate
Damage to Tourist Attractions and Recreation Amenities	Changes to revenues in the tourism and recreation industry, particularly those associated with distinct New England seasons (e.g., winter recreation, foliage viewing), recreational fishing, beach recreation (i.e., reduction in beach width due to sea level rise and coastal erosion), and tourism related to vulnerable historical landmarks.	Minimal	Disproportionate	Moderate
Economic Losses from Commercial Structure Damage and Business Interruptions	Reduction in economic outputs during closures resulting from flooding and storm damage to places of business, as well as reductions in economic output due to extreme weather shutdowns, utility and infrastructure disruptions, and climate-driven supply chains issues.	Minimal	Limited	Moderate

Note: Decrease in Marine Fisheries and Aquaculture Productivity is not a significant impact in this region.

Central Region Climate Impacts

The Commonwealth is already experiencing climate change impacts. The Central region is particularly vulnerable to climate hazards such as increasing temperatures and more extreme precipitation patterns, including associated flooding and droughts. An understanding of the current and future impacts of climate change allows community decision-makers to best tailor adaptation plans to meet the specific challenges faced in this region. This report summarizes the highest urgency climate impacts across Human, Infrastructure, Natural Environment, Governance, and Economy sectors for the Central region.

The highest urgency impacts are based on a review of the latest climate data developed for Massachusetts and a statewide assessment of potential climate impacts, informed by expert analysis and stakeholder engagement. The prioritized list will be an important input to the 2023 State Hazard Mitigation and Climate Adaptation Plan.



Regional Overview

Geography and Demographics*

- 55 cities and towns
- 960,200 people
- 27% minority
- 20% low-income
- 5% households with limited English language proficiency

Resources and Assets

- 303,600 residential properties
- 48,000 acres of agricultural land
- 15,400 miles of road
- 800,000 acres of forest
- 650 miles of coldwater fisheries streams

**For definitions of these demographic terms, please see Volume II of this report.*

Regional Climate Outlook

2030	2050	2070	2090
NEAR TERM The summer mean temperature could increase by 3.6°F from the historical period (1950-2013), worsening stress on electric transmission and utility distribution infrastructure.	**MID-CENTURY** The 1 percent annual chance river flood could be two times more likely to occur, increasing Blackstone River and other river flood risk.	**MID-LATE CENTURY** There could be 38 more days above 90°F, contributing to extreme heat health impacts.	**END OF CENTURY** The historical 10 percent annual chance daily rainfall event (2.8 to 4 inches) could occur five times more frequently.

Most Urgent Impacts by Sector for the Central Region

The Central region includes 55 cities and towns, including Worcester. Warming temperatures, resulting in more extreme heat days and shifting habitats, drive many of the most urgent impacts, but changes in intense rainfall events and droughts are also important, particularly for impacts on freshwater ecosystems, forest health, and agricultural productivity in this region. Below are the top two impacts per sector. The bookmark icons identify unique regional priorities, meaning for each sector, impacts that are not a top three most urgent impact statewide but are a top impact regionally.

Human

Reduction in Food Safety and Security due to production and supply chain issues, as well as spoilage during power outages.

Health and Cognitive Effects from Extreme Heat, including premature death and learning loss.

Infrastructure

Damage to Electric Transmission and Utility Distribution Infrastructure associated with heat stress and extreme storms.

Loss of Urban Tree Cover due to heat, drought, and increased pests.

Natural Environment

Freshwater Ecosystem Degradation due to warming waters, drought, and increased runoff.

Forest Health Degradation from warming temperatures, changing precipitation, extreme storms, and increasing pest occurrence.

Governance

Increase in Costs of Responding to Climate Migration, including planning for abrupt increases in local populations.

Increase in Demand for State and Municipal Government Services, including emergency response, food assistance, and state-sponsored health care.

Economy

Reduced Ability to Work, particularly for outdoor workers during extreme heat, as well as commute delays due to damaged road infrastructure.

Decrease in Agricultural Productivity as crop yields are impacted by precipitation patterns, extreme weather, pests, and other climate factors.

Featured Adaptation Effort

Integrated Vector-Borne Disease Control Program

Looking for alternatives to aerial spraying, the Town of Uxbridge sought funding for local monitoring and biological control of mosquito populations. Working cooperatively across Town Departments, the project also includes designs and permitting for two priority culverts, an update to the Town's Open Space and Recreation Plan, vernal pool identification/certification and education, and a public education campaign focused on climate change and preventing mosquito-transmitted disease.

This Massachusetts Climate Change Assessment (Climate Assessment) evaluates a broad range of climate change risks to the Commonwealth, including impacts on human health, natural resources, and public and private assets. The Climate Assessment will serve as a core component of the 2023 update to the State Hazard Mitigation and Climate Adaptation Plan (SHMCAP), specifically concerning the detailed hazard risk assessment. The outputs of the Climate Assessment are designed to meet the requirements for State Hazard Mitigation Planning documents, and to directly inform and provide a risk prioritization focus to the Mitigation Strategy.

The Climate Assessment evaluates **impacts** from **climate stressors** (temperature, precipitation, sea level rise, etc.) and **climate hazards** (extreme heat, flooding, droughts, etc.) across five **sectors** in the state. The Assessment identifies statewide priority impacts that require near-term adaptation action as well as regional priorities for **seven regions** of the Commonwealth.

This report provides regional detail on the impacts of climate change in the Central region of Massachusetts. For more details on the methods used in this assessment, please refer to the Statewide Report.

Regional Context

Regional Character and Demographics

The Central region is home to the state's second most populous city, Worcester, and several other mid-sized municipalities. Block groups with EEA's environmental justice designation are concentrated in these more urban areas, particularly Worcester, Leominster, and Fitchburg. Though the Central region accounts for nearly 14 percent of state population, it includes only nine percent and 12 percent of the state's minority and low-income residents, respectively. Regional employment largely tracks state trends, with the healthcare, retail, and manufacturing industries driving much of the regional economy.[26]

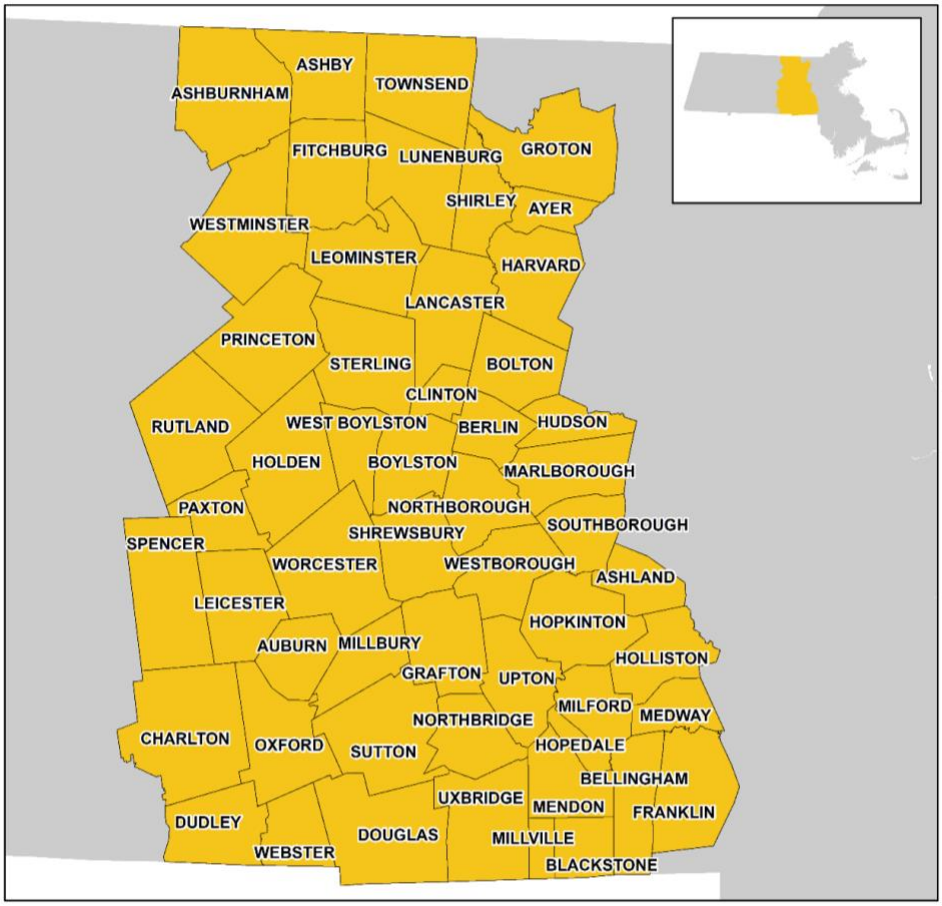
The region features forests and surface waters that provide key ecosystem services to the whole state. The Wachusett Reservoir is the state's second largest freshwater reservoir and provides a key water source for the Greater Boston Area and backup or emergency water for Worcester, Leominster, and Clinton within the region. The region's several state forests and reservations provide recreational opportunities, habitats, and water and air purification. Wachusett Mountain, home to one of the state's most popular ski areas, provides a recreation and tourism draw for the region.

The region boundary used for this assessment matches the Municipal Vulnerability Preparedness (MVP) program's Central region. All 55 municipalities in the region are engaged in climate adaptation planning through the MVP program, with many cities and towns having received further grant money for implementation of resilience projects.

[26] Central MA Workforce Development Board and North Central MA Workforce Investment Board. 2018. The Central MA Regional Workforce Blueprint. https://www.mass.gov/doc/central-regional-workforce-skills-planning-initiative-regional-blueprint/download

Cities and Towns in the Central Region

The MA Climate Change Assessment's Central region includes these 55 cities and towns, including Devens Enterprise Commission (not shown on the map).



Highlights of Future Climate Projections

The most important climate hazards for this region include changes to temperature extremes, changes in precipitation patterns, and consequent changes in the patterns of river flows that can lead to inland flooding. Some key findings of the climate change projections that may be important for this region over the 21st century include the following:

2030	2050	2070	2090
NEAR TERM	MID-CENTURY	MID-LATE CENTURY	END OF CENTURY
The summer mean temperature could increase by 3.6°F from the historical period (1950-2013), worsening stress on electric transmission and utility distribution infrastructure.	The 1 percent annual chance river flood could be two times more likely to occur, increasing Blackstone River and other river flood risk.	There could be 38 more days above 90°F, contributing to extreme heat health impacts.	The historical 10 percent annual chance daily rainfall event (2.8 to 4 inches) could occur five times more frequently.

Urgent Impacts in the Central Region

Table 13 presents the two most urgent impacts per sector for the Central region. The sections that follow provide additional details on the regional rankings for each sector. For more details on all impact assessment methodologies, see Chapter 2 of Volume II, the Statewide Report.

Table 13. Two Most Urgent Impacts by Sector for the Central Region

Human Sector

- **Reduction in Food Safety and Security** due to production and supply chain issues, as well as spoilage during power outages.
- **Health and Cognitive Effects from Extreme Heat**, including premature death and learning loss.

Infrastructure Sector

- **Damage to Electric Transmission and Distribution Infrastructure** associated with heat stress and extreme events.
- **Loss of Urban Tree Cover** due to heat, drought, and increased pests.

Natural Environment Sector

- **Freshwater Ecosystem Degradation** due to warming waters and increased runoff.
- **Forest Health Degradation** from warming temperatures, changing precipitation, extreme storms, and increasing pest occurrence.

Governance Sector

- **Increase in Costs of Responding to Climate Migration**, including planning for abrupt increases in local population.
- **Increase in Demand for State and Municipal Government Services**, including emergency response, food assistance, and state-sponsored health care.

Economy Sector

- **Reduced Ability to Work**, particularly for outdoor workers during extreme heat, as well as commute delays due to damaged road infrastructure.
- **Decrease in Agricultural Productivity** as crop yields are impacted by precipitation patterns, extreme weather, pests, and other climate factors.

Human Sector Impacts

Reduction in Food Safety and Security and Health and Cognitive Effects from Extreme Heat are the most urgent Human sector impacts in the Central region, with both projected to produce major magnitudes of consequence. Statewide, the impact of climate change on food security is most acute in rural areas like those that make up much of the Central region. Reduction in crop yields across the state and within the region plays a role in this—key commodity crop yields in the Central region could decline by 12 percent by 2030.[27] Statewide and national food supply networks are expected to help compensate for these losses, but those supply chains are increasingly at risk from extreme weather events, and price increases associated with yield declines and supply interruptions could further endanger the region's food security.

Extreme heat impacts also project to be significant, particularly in the Central region's more urban areas. Currently, three annual premature deaths are attributable to extreme temperature in the region, but approximately 35 additional premature deaths per year are expected as a result of climate change by the end of the century.[28] This estimate assumes that there would be no or limited further adaptation to extreme temperatures beyond those in place during the baseline period. Heat effects on cognition could further impact learning, productivity, and morbidity outcomes like emergency department visits. Health Effects from Degraded Air Quality, though a top impact statewide, is not a priority concern in this region due to the regional climate.

Table 14. Central Region Urgency Rankings for Human Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Reduction in Food Safety and Security	Temperature increases, spoilage, and power outages can lead to increased food contamination. Changes in food production and supply chain disruption linked to climate change will worsen existing food insecurity.	Moderate	Disproportionate	Moderate
Health and Cognitive Effects from Extreme Heat	Impacts of extreme heat episodes on health, learning, and workplace injuries - covers all health aspects of changes in frequency and severity of days with extreme temperatures.	Major	Potential	Moderate

[27] See Statewide report for more details. Estimates derived from application of USEPA. 2017. Multi-Model Framework for Quantitative Sectoral Impacts Analysis: A Technical Report for the Fourth National Climate Assessment. U.S. Environmental Protection Agency, EPA 430-R-17-001. and Beach, R., Y. C, A. Thomsom, X. Zhang, R. Jones, B. McCarl, A. Crimmins, J. Martinich, J. Cole, S. Ohrel, B. DeAngelo, J. McFarland, K. Strzepek, and B. Boehlert. 2015. Climate change impacts on US agriculture and forestry: benefits of global climate stabilization. Environmental Research Letters. doi:10.1088/1748-9326/10/9/095004.

[28] See Statewide report for more details. Estimates derived from application of Mills, D., Schwartz, J., Lee, M., Sarofim, M., Jones, R., Lawson, M., Duckworth, M., and Deck, L. (2014). Climate change impacts on extreme temperature mortality in select metropolitan areas in the United States. Climatic Change, 131, 83-95.

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Increase in Mental Health Stressors	Negative effects of weather and climate change on mental health, including a broad range of impacts on overall well-being associated mostly with temperature stress.	Moderate	Potential	Moderate
Increase in Vector Borne Diseases Incidence and Bacterial Infections	Increase in incidence of West Nile Virus, Lyme disease, and other diseases, and associated fatal and nonfatal outcomes, as a result of changes in temperature and an extended seasons for vectors and/or impact on bacterial loads.	Major	Limited	Moderate
Damage to Cultural Resources	Climate stressors can damage important cultural resources that hold special value to residents of the Commonwealth.	Minimal	Potential	Moderate
Health Effects from Aeroallergens and Mold	Impacts from extended pollen seasons, particularly on people with asthma or hay fever, and increases in exposure to mold spores associated with more frequent flood events and higher humidity conditions.	Minimal	Potential	Moderate
Emergency Service Response Delays and Evacuation Disruptions	Extreme storms cause delays in response time, potentially leading to loss of life. Extreme coastal storm surge events and inland flooding could flood evacuation routes, trapping residents, leading to increased loss of life and injuries.	Moderate	Limited	Moderate
Health Effects of Extreme Storms and Power Outages	Power outages and flooding, which could increase with more frequent extreme events, lead to a range of morbidity and sometimes fatal health outcomes and an increase in requests for emergency services.	Moderate	Limited	Moderate
Health Effects from Degraded Air Quality	Impacts of climate-induced changes in ambient and indoor air quality on health (e.g., premature loss of life, health care costs, missed school). Focused on changes from the direct impact of climate on particulate matter and ozone air quality, and the resulting health effects associated with these pollutants.	Moderate	Limited	Minimal

Infrastructure Sector Impacts

In the Infrastructure sector, Loss of Urban Tree Cover and Damage to Electric Transmission and Distribution Infrastructure are the Central region's most urgent impacts. Climate change is projected to stress urban trees through increased extreme event frequency, increased threat

from pests, and reduced water and soil quality, leading to more frequent tree mortality and higher management costs for municipalities. The Central region features a few urban centers, where projected temperature increases make urban tree coverage particularly valuable. For example, Worcester is the state's second most populous city, and 75 percent of the city's area falls within state-designated environmental justice block groups, but it has relatively low canopy coverage and is at disproportionate risk for urban tree loss. In these urban areas and throughout the rest of the region, Damage to Electric Transmission and Distribution Infrastructure is projected to have a major magnitude of consequence, with additional annual costs growing to $6 million by 2030; $12 million by 2050; $19 million by 2070; and $28 million by 2090.[29] These estimates consider a wide range of climate stressors and affected infrastructure, and costs are based on the need for repair activities in response to climate-related damage and failure. Damage to Inland Buildings, while projected to be significant statewide, is not expected to have a particularly large impact in the Central region, as changes in circulation patterns and drying conditions leading to a reduction in river flow.

Table 15. Central Region Urgency Rankings for Infrastructure Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Damage to Electric Transmission and Utility Distribution Infrastructure	Costs to repair transmission infrastructure failure associated with heat stress and extreme events that directly affect the transmission and distribution system. Includes wired communication and information technology systems.	Major	Potential	Moderate
Loss of Urban Tree Cover	Urban trees are susceptible to invasive pests and high heat/drought conditions and provide many services including mitigating heat island effects, pollution removal, etc.	Moderate	Disproportionate	Minimal
Damage to Roads and Loss of Road Service	Damage to roads from extreme precipitation, flooding, and temperature increases the need for repair and maintenance, and indirect effects of increased vehicle operating costs from driving on roads in poor condition. Includes effects on bridges and culverts at road crossings.	Extreme	Limited	Moderate
Reduction in Clean Water Supply	Addresses changes in water quantity and quality for water supplied for all human uses. Changes in precipitation patterns and saltwater intrusion can lead to impaired surface and groundwater supply available for municipal, industrial, commercial, and agricultural uses.	Major	Potential	Minimal

[29] See Statewide report for more details. Estimates derived from application of Fant, C., Boehlert, B., Strzepek, K., Larsen, P., White, A., Gulati, S., Li, Y., & Martinich, J. (2020). Climate change impacts and costs to U.S. electricity transmission and distribution infrastructure. Energy, 195. Doi:10.1016/j.energy.2020.116899

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Increased Risk of Dam Overtopping or Failure	Climate change could lead to more frequent overtopping of some, or all of the state dam safety program designated High or Significant Hazard dams, causing flooding of downstream areas.	Moderate	Potential	Minimal
Loss of Energy Production and Resources	Changes in temperature increase electricity demand and reduce production efficiency, requiring changes in the overall network cost of meeting electric demand. Effects on solar energy production potentially subject to flooding are also considered.	Moderate	Limited	Moderate
Damage to Inland Buildings	Addresses the risk of flooding to inland structures from rainfall (pluvial flooding) when drainage systems are overwhelmed by large rainstorms and rivers (fluvial flooding).	Minimal	Limited	Moderate
Damage to Rails and Loss of Rail/Transit Service	Extreme temperature events reduce useful life of track and cause buckling events, which also lead to indirect impacts from delays that occur due to track buckling and repair. Also addressed are effects of storms and sea level rise on subway and commuter rail operation.	Minimal	Limited	Moderate

Note: Damage to Coastal Buildings and Ports is not a relevant impact in this region.

Natural Environment Sector Impacts

Freshwater Ecosystem Degradation and Forest Health Degradation are both projected to have extreme magnitudes of consequence in the Central region. Climate change threatens freshwater ecosystems through increased nutrient loading and harmful algal bloom growth, increased contaminant concentrations during drought conditions, and shifting habitat regimes as air and water temperatures rise. The region's coldwater habitats and the fisheries they support are particularly at risk from increased temperatures. The region's forests are also at risk—though the effects of climate change on forest health are highly uncertain, the scale of transition and potential for lost ecosystem services due to expected climate-caused disturbances is expected to be significant. Statewide, a third of tree species are classified by the U.S. Forest Service as having low capacity for adapting to projected climate changes,[30] and an increased frequency of extreme events poses an additional threat to forests in the Central region.

[30] See Statewide report for more details. Estimates derived from application of US Forest Service Tree Atlas for Massachusetts: https://www.fs.usda.gov/nrs/atlas/combined/resources/summaries/states/Massachusetts.pdf and https://www.fs.usda.gov/nrs/atlas/combined/resources/summaries/states/

Table 16. Central Region Urgency Rankings for Natural Environment Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Freshwater Ecosystem Degradation	Rising temperature and changing precipitation patterns will lead to a reduction in water quality and changes in water quantity, resulting in changes to habitat quality in rivers, streams, ponds, lakes, and freshwater wetlands.	Extreme	Potential	Minimal
Forest Health Degradation	Warming temperatures, changing precipitation, increasing pest occurrence, more frequent and intense storms, and increased wildfire risk may cause a decline in forest health (e.g., biodiversity, biomass, resiliency) along with the loss of carbon sequestration and other ecosystem services. Impacts vary by forest type.	Extreme	Potential	Moderate
Shifting Distribution of Native and Invasive Species	Changing climatic conditions shift and eliminate suitable habitat for native species (flora and fauna), increase the risk of new species introductions, and increases competition from established invaders, potentially causing losses in native biodiversity and loss of culturally important species.	Major	Potential	Moderate
Soil Erosion	Increase in extreme precipitation and potential loss in vegetation and change in vegetation type, particularly along riverbanks but also in forests, on agricultural land, and in other landscapes.	Moderate	Potential	Moderate

Note: Coastal Wetland Degradation, Marine Water Ecosystem Degradation, and Coastal Erosion are not significant impacts in this region.

Governance Sector Impacts

In line with the rest of the state, the Central region's most urgent Governance sector impacts are Increase in Costs of Responding to Climate Migration, Increase in Demand for State and Municipal Government Services, and Reduction in State and Municipal Revenues. The consequences of climate migration are difficult to assess, but this impact is classified as having a major magnitude of consequence in the region based on review of existing literature on climate migration prospects and the likelihood that Massachusetts (and particularly urban centers like Worcester) could be a receiving zone for climate migrants based on a relative assessment of climate hazards. Climate migration and other threats are expected to increase demand for government services. The need to increase expenditures to maintain the current level of governmental services represents a potentially important stressor for the local governments of the Central region. For this region there could be increased needs for MassHealth (connected to extreme heat impacts on health), food security support (which would expand the need for state-level SNAP programs), and emergency response resulting from climate change (particularly connected to impassable roads during inland flooding events). Many of these impacts are expected to be concentrated among those residing in low-income block groups.

Table 17. Central Region Urgency Rankings for Governance Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Increase in Costs of Responding to Climate Migration	Costs and stresses to governments accommodating and/or preparing for forced and voluntary human migration of populations in response to climate threats or related economic pressures. Includes intra-state, inter-state, and international in- and out-migration, and is generally, more abrupt than routine population changes in response to non-climate stressors (such as economic development or decline).	Major	Potential	Extreme
Increase in Demand for State and Municipal Government Services	Climate change serves as a threat multiplier, which can increase the need for expenditures to meet existing government service. Examples include capital, equipment, or operating costs for emergency response provision and state sponsored health programs.	Major	Potential	Moderate
Reduction in State and Municipal Revenues	State and municipal revenue streams impacted through property tax loss following structure damage of any type, from any hazard, and sales tax losses associated with business interruptions or effects on industrial activities.	Moderate	Potential	Moderate
Increase in Need for State and Municipal Policy Review and Adaptation Coordination	State agencies and municipalities may require additional full-time employees and specialized training to meet the challenges of climate change. Specifically, state and municipal staff will need capacity to provide adaptation planning support and to review and modify policies in response to changing conditions and uncertainty associated with climate change.	Minimal	Potential	Minimal
Damage to Inland State and Municipal Buildings and Land	Risk to vulnerable state and municipal owned structures and other property from flooding, extreme heat, and extreme storms. Includes damage repair costs and service losses during closures.	Minimal	Limited	Minimal

Note: Damage to Coastal State and Municipal Buildings and Land is not a significant impact in the region.

Economy Sector Impacts

Reduced Ability to Work and Decrease in Agricultural Productivity are the Central region's most urgent Economy sector impacts. Climate change hazards can make it difficult for people to work because of dangerous conditions (i.e., extreme heat), transportation disruptions, and illness. In the Central region, the primary concern for workers in the Economy sector is reduced ability to work during extreme heat. Workers in the region in high-risk industries (those exposed to outdoor conditions) are projected to lose 31 hours per worker each year by 2050 and 128 hours

per worker each year by 2090,[31] the highest in the Commonwealth by the end of the century. This impact has disproportionate exposure based on the composition of the most affected workforce. In the Worcester metropolitan area workforce, the share of non-Asian minority workers in the laborer occupation group is 253 percent of the same group's representation in the full workforce.[32] While agriculture plays a smaller role in the Central region than some other regions, impacts on yields have potentially significant impacts on local economies and regional food systems. Key commodity crop yields in the Central region could decline by 12 percent by 2030, and by 14 percent by 2070,[33] and these reduced yields carry potentially disproportionate impacts for both farmworkers and communities that rely on local agriculture.

Table 18. Central Region Urgency Rankings for Economy Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Reduced Ability to Work	More frequent extreme heat days lead to lost wages and decreased productivity, as do increasing incidence of climate-induced health effects (e.g., asthma, allergies, vector borne disease, extreme heat). Weather-induced disruptions to transportation and ability to work may also lead to lost wages and worker productivity.	Extreme	Disproportionate	Moderate
Decrease in Agricultural Productivity	Reduction in crop yields for major agricultural products including field crops and tree products due to changing temperature and precipitation patterns, extreme weather, loss of pollinators, and others.	Major	Potential	Moderate
Reduction in the Availability of Affordably Priced Housing	An increase in demand for housing that is affordable and a decrease in supply worsens the scarcity of affordably priced housing. Demand for housing that is affordable can result if people are forced to relocate either due to direct damage to existing housing or because of climate-related economic pressures. The supply of affordably priced housing is reduced due to direct physical damage from climate impacts and potentially higher construction costs to increase resilience to threats from climate change.	Minimal	Potential	Extreme

[31] See Statewide report for more details. Estimates derived from application of Neidell, M., Graff Zivin, J., Sheahan, M., Willwerth, J., Fant, C., Sarofim, M. and Martinich, J., 2021. Temperature and work: Time allocated to work under varying climate and labor market conditions. PloS one, 16(8), p.e0254224.

[32] Labor category includes physical work in construction, carpentry, agriculture, and landscaping. Data from Center for Employment Equity. Diversity Analytics: Compare Within State. University of Massachusetts Amherst. Available at https://www.umass.edu/employmentequity/diversity-analytics/visualization/Compare%20within%20State.

[33] See Statewide report for more details. Estimates derived from application of USEPA (2017) and Beach et al. (2015).

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Damage to Tourist Attractions and Recreation Amenities	Changes to revenues in the tourism and recreation industry, particularly those associated with distinct New England seasons (e.g., winter recreation, foliage viewing), recreational fishing, beach recreation (i.e., reduction in beach width due to sea level rise and coastal erosion), and tourism related to vulnerable historical landmarks.	Minimal	Potential	Moderate
Economic Losses from Commercial Structure Damage and Business Interruptions	Reduction in economic outputs during closures resulting from flooding and storm damage to places of business, as well as reductions in economic output due to extreme weather shutdowns, utility and infrastructure disruptions, and climate-driven supply chains issues.	Minimal	Limited	Moderate

Note: Decrease in Marine Fisheries and Aquaculture Productivity is not a significant impact in this region.

Eastern Inland Region Climate Impacts

The Commonwealth is already experiencing climate change impacts. The Eastern Inland region is particularly vulnerable to climate hazards such as increasing temperatures, more extreme precipitation, and associated flooding. An understanding of the current and future impacts of climate change allows community decision-makers to best tailor adaptation plans to meet the specific challenges faced in this region. This report summarizes the highest urgency climate impacts across Human, Infrastructure, Natural Environment, Governance, and Economy sectors for the Eastern Inland region.

The highest urgency impacts are based on a review of the latest climate data developed for Massachusetts and a statewide assessment of potential climate impacts, informed by expert analysis and stakeholder engagement. The prioritized list will be an important input to the 2023 State Hazard Mitigation and Climate Adaptation Plan.

Regional Overview

Geography and Demographics*

- 88 cities and towns
- 2,112,500 people
- 31% minority
- 17% low-income
- 5% households with limited English language proficiency

Resources and Assets

- 267,000 residential properties
- 24,000 commercial properties
- 27,400 miles of road
- 5,500 miles of rail

**For definitions of these demographic terms, please see Volume II of this report.*

Regional Climate Outlook

2030	2050	2070	2090
NEAR TERM The summer mean temperature could increase by 3.6°F from the historical period (1950-2013), worsening stress on electric transmission and utility distribution infrastructure.	**MID-CENTURY** The 1 percent annual chance river flood could be two times more likely to occur, increasing Merrimack River and other river flood risk.	**MID-LATE CENTURY** There could be 58 fewer days below freezing, increasing the chance of ticks overwintering and reducing winter recreation opportunities.	**END OF CENTURY** The historical 10 percent annual chance daily rainfall event (2.8 to 4 inches) could occur four times more frequently.

Most Urgent Impacts by Sector for the Eastern Inland Region

The largest region by population, this region is home to significant transportation and housing infrastructure. Priority impacts suggest a need for maintaining infrastructure while protecting remaining natural resources. Below are the top two impacts per sector (three listed for tied scores). The bookmark icons identify unique regional priorities, meaning for each sector, impacts that are not a top three most urgent impact statewide but are a top two impact regionally.

Human

Increase in Vector Borne Diseases Incidence and Bacterial Infections, including West Nile Virus and Lyme disease due to more favorable conditions for ticks and mosquitoes.

Reduction in Food Safety and Security due to production and supply chain issues, as well as spoilage during power outages.

Infrastructure

Damage to Electric Transmission and Utility Distribution Infrastructure associated with heat stress and extreme events.

Damage to Inland Buildings from heavy rainfall and overwhelmed drainage systems.

Damage to Rails and Loss of Rail/ Transit Service, including flooding and track buckling during high heat events.

Natural Environment

Freshwater Ecosystem Degradation due to warming waters, drought, and increased runoff.

Forest Health Degradation from warming temperatures, changing precipitation, increasing wildfire frequency, and increasing pest occurrence.

Governance

Increase in Costs of Responding to Climate Migration, including planning for abrupt changes in local populations.

Increase in Demand for State and Municipal Government Services, including emergency response, food assistance, and state-sponsored health care.

Economy

Reduced Ability to Work, particularly for outdoor workers during extreme heat, as well as commute delays due to damaged infrastructure.

Reduction in the Availability of Affordably Priced Housing from direct damage (e.g., flooding) and the scarcity caused by increased demand.

Featured Adaptation Effort

Traphole Brook Flood Prevention and Stream Restoration Project

The Town of Norwood partnered with the Neponset River Watershed Association to remove the Mill Pond Dam, which was at risk of failure during the kind of major storm events that are increasing due to climate change. Restoring the natural flow of the brook significantly reduces flood risk for abutters and improves aquatic habitat conditions.

This Massachusetts Climate Change Assessment (Climate Assessment) evaluates a broad range of climate change risks to the Commonwealth, including impacts on human health, natural resources, and public and private assets. The Climate Assessment will serve as a core component of the 2023 update to the State Hazard Mitigation and Climate Adaptation Plan (SHMCAP), specifically concerning the detailed hazard risk assessment. The outputs of the Climate Assessment are designed to meet the requirements for State Hazard Mitigation Planning documents, and to directly inform and provide a risk prioritization focus to the Mitigation Strategy.

The Climate Assessment evaluates **impacts** from **climate stressors** (temperature, precipitation, sea level rise, etc.) and **climate hazards** (extreme heat, flooding, droughts, etc.) across five **sectors** in the state. The Assessment identifies statewide priority impacts that require near-term adaptation action as well as regional priorities for **seven regions** of the Commonwealth.

This report provides regional detail on the impacts of climate change in the Eastern Inland region of Massachusetts. For more details on the methods used in this assessment, please refer to the Statewide Report.

Regional Context

Regional Character and Demographics

The Eastern Inland region's 2.1 million people represent more than 30 percent of the state's population. The region has a relatively low proportion (22 percent) of the state's environmental justice block groups as designated by EEA. Because of its size, population, and proximity to the Greater Boston area, the region's network of transportation infrastructure is extensive, with more than 27 thousand miles of road (27 percent of the state's road mileage) and 5.5 thousand miles of rail (76 percent of the state's rail mileage). Many residents make use of this transportation infrastructure to commute to neighboring cities and coastal areas for work, but the region also has a growing economy and features the largest number of commercial properties in the state. The regional economy is driven by many of the industries common across the state, including healthcare, manufacturing, and professional services.[34,35,36]

Ecosystems in the Eastern Inland region face particularly high pressure from land use changes. Expanded development of urban centers threatens the region's forests, parks, and surface waters, and as climate pressures push people and infrastructure further inland, these threats to the region's natural resources will likely increase.

[34] Greater Lowell Workforce Development Board, North Shore Workforce Investment Board, Merrimack Valley Workforce Development Board. 2018. Northeast Labor Market Blueprint. https://www.mass.gov/doc/northeast-regional-workforce-skills-planning-initiative-regional-blueprint/download

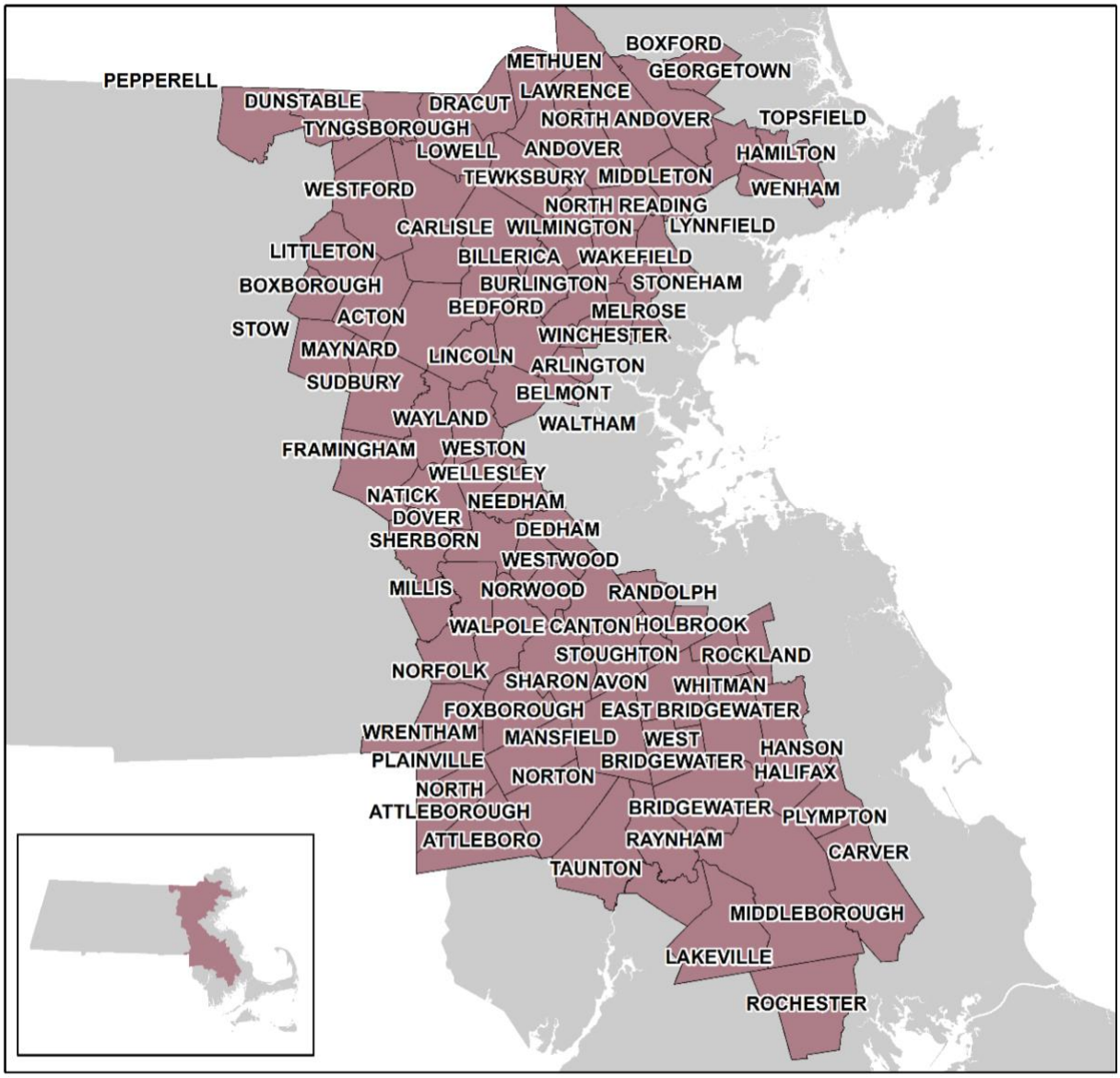
[35] UMass Donahue Institute. 2018. Greater Boston Workforce Planning Blueprint. https://www.mass.gov/doc/greater-boston-workforce-planning-blueprint/download

[36] Southeastern Massachusetts Workforce Development Team. 2018. Southeastern Massachusetts Labor Market Blueprint. https://www.mass.gov/doc/southeast-regional-workforce-skills-planning-initiative-regional-blueprint/download

The Eastern Inland region boundary used for this assessment overlaps the inland areas of the Municipal Vulnerability Preparedness (MVP) program's Northeast, Greater Boston, and Southeast regions. Nearly all municipalities in the region are actively engaged in climate resilience planning and adaptation action through the MVP program.

Cities and Towns in the Eastern Inland Region

The MA Climate Change Assessment's Eastern Inland region includes these 88 cities and towns.



Highlights of Future Climate Projections

The most important climate hazards for this region include changes to temperature extremes, changes in precipitation patterns, and consequent changes in the patterns of river flows that can lead to inland flooding. Fewer cold winter days could also increase the likelihood that more of the ticks which cause Lyme disease can successfully overwinter, increasing the chance of

interactions with population of the Eastern Inland region. Some key findings of the climate change projections that may be important for this region over the 21st century include the following:

2030	2050	2070	2090
NEAR TERM	MID-CENTURY	MID-LATE CENTURY	END OF CENTURY
The summer mean temperature could increase by 3.6°F from the historical period (1950-2013), worsening stress on electric transmission and utility distribution infrastructure.	The 1 percent annual chance river flood could be two times more likely to occur, increasing Merrimack River and other river flood risk.	There could be 58 fewer days below freezing, increasing the chance of ticks overwintering and reducing winter recreation opportunities.	The historical 10 percent annual chance daily rainfall event (2.8 to 4 inches) could occur four times more frequently.

Urgent Impacts in the Eastern Inland Region

Table 19 presents the two most urgent impacts per sector for the Eastern Inland region (more than two impacts are listed in the case of ties). The sections that follow provide additional details on the regional rankings for each sector. For more details on all impact assessment methodologies, see Chapter 2 of Volume II, the Statewide Report.

Table 19. Two Most Urgent Impacts by Sector for the Central Region

Human Sector

- **Increase in Vector Borne Diseases Incidence and Bacterial Infections**, including West Nile Virus and Lyme disease due to more favorable conditions for ticks and mosquitoes.
- **Reduction in Food Safety and Security** due to production and supply chain issues, as well as spoilage during power outages.

Infrastructure Sector

- **Damage to Electric Transmission and Utility Distribution Infrastructure** associated with heat stress and extreme events.
- **Damage to Inland Buildings** from heavy rainfall and overwhelmed drainage systems.
- **Damage to Rails and Loss of Rail/Transit Service**, including flooding and track buckling during high heat events.

Natural Environment Sector

- **Freshwater Ecosystem Degradation** due to warming waters, drought, and increased runoff.
- **Forest Health Degradation** from warming temperatures, changing precipitation, increasing wildfire frequency, and increasing pest occurrence.

Governance Sector

- **Increase in Costs of Responding to Climate Migration**, including planning for abrupt changes in local populations.
- **Increase in Demand for State and Municipal Government Services**, including emergency response, food assistance, and state-sponsored health care.

Economy Sector

- **Reduced Ability to Work**, particularly for outdoor workers during extreme heat, as well as commute delays due to damaged infrastructure.
- **Reduction in the Availability of Affordably Priced Housing** from direct damage (e.g., flooding) and the scarcity caused by increased demand.

Human Sector Impacts

The largest region by population, with over 2 million residents, the Eastern Inland region is projected to experience large effects of climate change in the Human Sector. The most urgent impact is the Increase in Vector Borne Diseases Incidence and Bacterial Infections, which is projected to have an extreme magnitude of consequence and disproportionate exposure. Currently, approximately 960 cases of Lyme Disease are reported annually in the Eastern Inland

region.[37] 490 additional annual cases of Lyme disease are projected to occur in the region in the near term (2030), with approximately 3,800 additional cases attributable to climate change by 2090.[38] Currently, there are approximately 2,600 annual cases of vibriosis in the Eastern Inland region, most associated with consumption of raw seafood, which accounts for 44 percent of statewide cases. In the near term (2030), an additional 920 cases attributable to climate change are projected to occur in the region, with approximately 4,000 additional cases by 2090.[39] The second highest priority. Other food-related concerns also top the list in this region. One of the largest food distribution centers in Massachusetts is located in Everett and supplies consumers in the Eastern Inland region; it also sits in the 100-year floodplain of the Mystic River, where it may be vulnerable to flooding, potentially leading to interruption of food supply chains. This risk, combined with potentially lower agricultural production in the Commonwealth and beyond, and risks of spoilage and contamination due to power outages and high heat, makes this an urgent impact with disproportionate exposure. Health and Cognitive Effects from Extreme Heat is another impact with projected extreme consequences, however the exposure is not found to be disproportionate within the region.

Table 20. Eastern Inland Urgency Rankings for Human Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Increase in Vector Borne Diseases Incidence and Bacterial Infections	Increase in incidence of West Nile Virus, Lyme disease, and other diseases, and associated fatal and nonfatal outcomes, as a result of changes in temperature and an extended seasons for vectors and/or impact on bacterial loads.	Extreme	Disproportionate	Moderate
Reduction in Food Safety and Security	Temperature increases, spoilage, and power outages can lead to increased food contamination. Changes in food production and supply chain disruption linked to climate change will worsen existing food insecurity.	Moderate	Disproportionate	Moderate
Increase in Mental Health Stressors	Negative effects of weather and climate change on mental health, including a broad range of impacts on overall well-being associated mostly with temperature stress.	Major	Potential	Moderate
Health and Cognitive Effects from Extreme Heat	Impacts of extreme heat episodes on health, learning, and workplace injuries - covers all health aspects of changes in frequency and severity of days with extreme temperatures.	Extreme	Limited	Moderate

[37] Massachusetts Department of Public Health. 2014, Lyme Disease Surveillance in Massachusetts. Available at https://www.mass.gov/lists/tick-borne-disease-surveillance-summaries-and-data#lyme-disease-surveillance-data- Data averaged for 2010 to 2014.

[38] Author's analysis of Couper, L.I., MacDonald, A.J., and Mordecai, E.A. 2020. Impact of prior and projected climate change on U.S. Lyme disease incidence. Global Change Biology, 27(4), 738-754.

[39] Sheahan, M., Gould, C., Neumann, J., Kinney, P., Hoffmann, S., Fant, C., Wang, X., and Kolian, M. 2022. The Influence of Climate Change on Vibriosis in the United States: Projected Health and Economic Impacts for the 21st Century. Environmental Health Perspectives. [accepted, in print]

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Damage to Cultural Resources	Climate stressors can damage important cultural resources that hold special value to residents of the Commonwealth.	Moderate	Potential	Moderate
Health Effects of Extreme Storms and Power Outages	Power outages and flooding, which could increase with more frequent extreme events, lead to a range of morbidity and sometimes fatal health outcomes and an increase in requests for emergency services.	Moderate	Potential	Moderate
Health Effects from Aeroallergens and Mold	Impacts from extended pollen seasons, particularly on people with asthma or hay fever, and increases in exposure to mold spores associated with more frequent flood events and higher humidity conditions.	Moderate	Potential	Moderate
Health Effects from Degraded Air Quality	Impacts of climate-induced changes in ambient and indoor air quality on health (e.g., premature loss of life, health care costs, missed school). Focused on changes from the direct impact of climate on particulate matter and ozone air quality, and the resulting health effects associated with these pollutants.	Major	Potential	Minimal
Emergency Service Response Delays and Evacuation Disruptions	Extreme storms cause delays in response time, potentially leading to loss of life. Extreme coastal storm surge events and inland flooding could flood evacuation routes, trapping residents, leading to increased loss of life and injuries.	Moderate	Limited	Moderate

Infrastructure Sector Impacts

The priority impacts in the Eastern Inland region match those in the statewide assessment, primarily due to the large inventory of infrastructure in this region. Eastern Inland region contains over 5,000 miles of rail (the next highest region, Greater Connecticut River Valley, has 500 miles) and over 625,000 residential properties (compared to the next highest, Boston Harbor region, with 380,000), among other transportation and structure infrastructure.

There are three impacts tied for the most urgent ranking in this region. Damage to Electric Transmission and Utility Distribution Infrastructure, from stressors such as extreme temperature, extreme rain, lightning, vegetation growth,[40] wildfire activity, and coastal flooding in this region are considered extreme and are the highest among regions in the Commonwealth. Available estimates could grow to an additional $15 million in 2030; $30 million annually in 2050; $50 million in 2070; and $75 million annually by 2090.[41] The Eastern

[40] Vegetation growth could be accelerated under a warmer climate.

[41] Author analysis of data and methods from: Fant, C., B. Boehlert, K. Strzepek, P. Larsen, A. White, S. Gulati, Y. Li, and J. Martinich (2020). Climate change impacts and costs to U.S. electricity transmission and distribution infrastructure. Energy, 195, 116899, doi:10.1016/j.energy.2020.116899. Available online at https://www.sciencedirect.com/science/article/pii/S0360544220300062

Inland region also has a high risk for Damage to Inland Buildings when measured as a percentage of the total structure value in the region. The region is expected to experience the largest absolute annual economic impact of inland flooding in the Commonwealth by 2050 ($27 million annually). These economic damages attributed to climate change could double by 2090, and account for about 50 percent or more of total estimated inland flood damages to residences from 2050 onward.[42] Finally, Damage to Rails and Loss of Rail/Transit Service is an important impact category in the region, particularly because of the role rail (both commuter line and the subway, or the "T") play in connecting the region to Boston and the hub of economic activity. The cost of repairing tracks due to damage incurred as a result of extreme heat deforming rails for the Eastern Inland portion of commuter and freight rail lines are the largest among regions in the state. Economic impact estimates for the additional costs climate change could impose grow from $2.2 million in 2050 to $13 million in 2090 and account for more than one-third of the overall estimated incremental costs for rail maintenance in the Commonwealth as a whole.[43]

Table 21. Eastern Inland Urgency Rankings for Infrastructure Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Damage to Electric Transmission and Utility Distribution Infrastructure	Costs to repair transmission infrastructure failure associated with heat stress and extreme events that directly affect the transmission and distribution system. Includes wired communication and information technology systems.	Major	Disproportionate	Moderate
Damage to Inland Buildings	Addresses the risk of flooding to inland structures from rainfall (pluvial flooding) when drainage systems are overwhelmed by large rainstorms and rivers (fluvial flooding).	Major	Disproportionate	Moderate
Damage to Rails and Loss of Rail/Transit Service	Extreme temperature events reduce useful life of track and cause buckling events, which also lead to indirect impacts from delays that occur due to track buckling and repair. Also addressed are effects of storms and sea level rise on subway and commuter rail operation.	Major	Disproportionate	Moderate
Loss of Urban Tree Cover	Urban trees are susceptible to invasive pests and high heat/drought conditions and provide many services including mitigating heat island effects, pollution removal, etc.	Moderate	Disproportionate	Minimal

[42] The results are based primarily on data from: Wobus, C.W., Porter, J., Lorie, M., Martinich, J., & Bash, R. (2021). Climate change, riverine flood risk and adaptation for the conterminous United States. Environmental Research Letters. doi: 10.1088/1748-9326/ac1bd7. Data on damage ratios by block group and integer degree were downloaded from: www.epa.gov/CIRA/social-vulnerability-report, see data supporting Appendix I.

[43] Analysis based on Neumann, J.E., Chinowsky, P., Helman, J., Black, M., Fant, C., Strzepek, K., and Martinich, J. (2021) Climate effects on US infrastructure: the economics of adaptation for rail, roads, and coastal development. Climatic Change 167, 44 (2021). https://doi.org/10.1007/s10584-021-03179-w and Chinowsky P, Helman J, Gulati S, Neumann J, Martinich J (2017) Impacts of climate change on operation of the US rail network. Transport Policy. https://doi.org/10.1016/j.tranpol.2017.05.007

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Reduction in Clean Water Supply	Addresses changes in water quantity and quality for water supplied for all human uses. Changes in precipitation patterns and saltwater intrusion can lead to impaired surface and groundwater supply available for municipal, industrial, commercial, and agricultural uses.	Moderate	Potential	Moderate
Damage to Roads and Loss of Road Service	Damage to roads from extreme precipitation, flooding, and temperature increases the need for repair and maintenance, and indirect effects of increased vehicle operating costs from driving on roads in poor condition. Includes effects on bridges and culverts at road crossings.	Major	Limited	Moderate
Damage to Coastal Buildings and Ports	Sea level rise, coastal erosion, and storm surge, as well as high wind events from tropical and extra-tropical storms, will cause increased damage to coastal structures, land, and related infrastructure such as ports and marinas.	Minimal	Disproportionate	Insignificant
Loss of Energy Production and Resources	Changes in temperature increase electricity demand and reduce production efficiency, requiring changes in the overall network cost of meeting electric demand. Effects on solar energy production potentially subject to flooding are also considered.	Moderate	Limited	Minimal
Increased Risk of Dam Overtopping or Failure	Climate change could lead to more frequent overtopping of some, or all of the state dam safety program designated High or Significant Hazard dams, causing flooding of downstream areas.	Minimal	Limited	Minimal

Natural Environment Sector Impacts

Open space and natural environments in the region, particularly freshwater and forest habitats, are expected to face increased pressure from the stressors of climate change. Many of the freshwater resources in the region are currently listed on the states Impaired Waters list for waterbodies not meeting surface water quality standards.[44] Intense precipitation events scour and erode stream channels, and increase nutrient and contaminant concentrations in freshwater bodies. This effect is magnified in watersheds with high levels of impervious surface coverage. The region is also home to over one million acres of forest. Climate change is expected to reduce the flow of ecosystem services from forests through changing composition (as species ranges shift with changing temperatures), increased pests, and more tree mortality during extreme storms.

[44] Analysis of GIS data: MassDEP. 2022. MassDEP 2018/2020 Integrated List of Waters (305(b)/303(d)). February 2022. Available at: https://www.mass.gov/info-details/massgis-data-massdep-20182020-integrated-list-of-waters-305b303d

Table 22. Eastern Inland Urgency Rankings for Natural Environment Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Freshwater Ecosystem Degradation	Rising temperature and changing precipitation patterns will lead to a reduction in water quality and changes in water quantity, resulting in changes to habitat quality in rivers, streams, ponds, lakes, and freshwater wetlands.	Extreme	Potential	Moderate
Forest Health Degradation	Warming temperatures, changing precipitation, increasing pest occurrence, more frequent and intense storms, and increased wildfire risk may cause a decline in forest health (e.g., biodiversity, biomass, resiliency) along with the loss of carbon sequestration and other ecosystem services. Impacts vary by forest type.	Major	Potential	Moderate
Shifting Distribution of Native and Invasive Species	Changing climatic conditions shift and eliminate suitable habitat for native species (flora and fauna), increase the risk of new species introductions, and increases competition from established invaders, potentially causing losses in native biodiversity and loss of culturally important species.	Major	Potential	Minimal
Soil Erosion	Increase in extreme precipitation results in increased erosion and loss of vegetation or changes in vegetation type, particularly along riverbanks but also in forests and in a number of landscapes.	Minimal	Potential	Moderate

Note: Coastal Wetland Degradation, Marine Ecosystem Degradation, and Coastal Erosion are not significant impacts in this region.

Governance Sector Impacts

The region could face significant costs as receivers of climate migrants from other areas of the Commonwealth (particularly from areas at risk of sea level rise) and beyond. A study of sea level rise driven migration found that most American households displaced due to environmental phenomena migrate to nearby urban job-growth centers; within Massachusetts, this outcome may be observed as movement from coastal regions of Massachusetts to nearby but inland regions, such as the medium-sized urban or suburban areas of the Eastern Inland region, which also maintain commuting access to the largest job centers in the state in the Boston Harbor region.[45] The costs of climate migration could include specialized housing provision, both short-term and medium-term; social services; increased educational costs to school systems; and pressure on existing public infrastructure. Relatively few adaptation plans and actions have been implemented to address this potential cost, resulting in an extreme adaptation gap. Increase in Demand for State and Municipal Government Services, even for the

[45] Hauer, M.E., Fussell, E., Mueller, V. et al. 2020. Sea-level rise and human migration. Nat Rev Earth Environ 1, 28–39. https://doi.org/10.1038/s43017-019-0002-9

existing population, is another impact with projected major consequences, with the potential for disproportionate exposure. For this region there could be increased needs for MassHealth (connected to extreme heat impacts on health), food security support (which would expand the need for state-level SNAP programs), and emergency response as a result of climate change (particularly connected to impassable roads during inland flooding events).

Table 23. Eastern Inland Urgency Rankings for Governance Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Increase in Costs of Responding to Climate Migration	Costs and stresses to governments accommodating and/or preparing for forced and voluntary human migration of populations in response to climate threats or related economic pressures. Includes intra-state, inter-state, and international in- and out-migration, and is generally more abrupt than routine population changes in response to non-climate stressors (such as economic development or decline).	Major	Potential	Extreme
Increase in Demand for State and Municipal Government Services	Climate change serves as a threat multiplier, which can increase the need for expenditures to meet existing government service. Examples include capital, equipment, or operating costs for emergency response provision and state sponsored health programs.	Major	Potential	Moderate
Reduction in State and Municipal Revenues	State and municipal revenue streams impacted through property tax loss following structure damage of any type, from any hazard, and sales tax losses associated with business interruptions or effects on industrial activities.	Moderate	Limited	Moderate
Increase in Need for State and Municipal Policy Review and Adaptation Coordination	State agencies and municipalities may require additional full-time employees and specialized training to meet the challenges of climate change. Specifically, state and municipal staff will need capacity to provide adaptation planning support and to review and modify policies in response to changing conditions and uncertainty associated with climate change.	Minimal	Potential	Minimal
Damage to Inland State and Municipal Buildings and Land	Risk to vulnerable state and municipal structures and other property from flooding, extreme heat, and extreme storms. Includes damage repair costs and service losses during closures.	Minimal	Limited	Minimal

Note: Damage to Coastal State and Municipal Buildings and Land is not a significant impact in this region.

Economy Sector Impacts

The most urgent impacts for the region in the Economy sector are the Reduced Ability to Work and the Reduction in the Availability of Affordably Priced Housing. Eastern Inland region workers in high-risk industries (those exposed to outdoor conditions) are projected to lose 34 hours per worker each year by 2050 and 127 hours per worker each year by 2090, nearly the highest in the Commonwealth by the end of the century.[46] The high projected incidence of air pollution morbidity, vector-borne disease morbidity, and heat-related occupational inability to work combine uniquely in this region to make it most vulnerable to a reduced ability to work. As described in the Infrastructure sector discussion, this region has the highest projected climate-driven above ground rail maintenance costs of any region in the Commonwealth by 2090, suggesting disruptions could be a significant issue.[47] A 2018 study of MBTA passengers in Massachusetts found that about 90 percent of commuter rail and ferry trips were commutes between home and work. [48]

Climate change could affect the availability of affordably priced housing in multiple ways, including through coastal and inland flood risks which can directly or indirectly affect both publicly owned housing and the market for affordably priced housing. The current need for affordably priced housing in the Eastern Inland region is exacerbated by relatively high housing prices overall in many parts of this region. There may be less federally subsidized affordable housing in the region. [49] However, this region has a relatively high potential inland flood risk to housing which is within the 25th percentile housing cost on the private market – the annual expected flood damages to this class of housing in the region could be $3 million in 2030 but jumps to $14 million in 2050 and $25 million annually by 2090.[50]

Table 24. Eastern Inland Urgency Rankings for Economy Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Reduced Ability to Work	More frequent extreme heat days leads to lost wages and decreased productivity, as do increasing incidence of climate-induced health effects (e.g., asthma, allergies, vector borne disease, extreme heat). Weather-induced disruptions to transportation and ability to work may also lead to lost wages and worker productivity. Impacts are felt	Extreme	Disproportionate	Moderate

[46] Authors analysis of Neidell, M., Graff Zivin, J., Sheahan, M., Willwerth, J., Fant, C., Sarofim, M. and Martinich, J., 2021. Temperature and work: Time allocated to work under varying climate and labor market conditions. PloS one, 16(8), p.e0254224.

[47] Chinowsky P, Helman J, Gulati S, Neumann J, Martinich J (2017) Impacts of climate change on operation of the US rail network. Transport Policy. https://doi.org/10.1016/j.tranpol.2017.05.007

[48] Central Transportation Planning Staff. 2018. MBTA 2015-17 Systemwide Passenger Survey. Directed by the Boston Region Metropolitan Planning Organization. Available at: https://www.ctps.org/dv/mbtasurvey2018/2015_2017_Passenger_Survey_Final_Report.pdf

[49] Buchanan, M.K., Kulp, S., Cushing, L., Morello-Frosch, R., Nedwick, T. and Strauss, B., 2020. Sea level rise and coastal flooding threaten affordable housing. Environmental Research Letters, 15(12), p.124020.

[50] American Community Survey property and structure value; U.S. EPA data at www.epa.gov/CIRA; and Project Team Analysis.

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
	most by workers in outdoor industries, those who rely on public transportation, and those who care for others at home.			
Reduction in the Availability of Affordably Priced Housing	An increase in demand for housing that is affordable and a decrease in supply worsens the scarcity of affordably priced housing. Demand for housing that is affordable can result if people are forced to relocate either due to direct damage to existing housing or because of climate-related economic pressures. The supply of affordably priced housing is reduced due to direct physical damage from climate impacts and potentially higher construction costs to increase resilience to threats from climate change.	Moderate	Disproportionate	Extreme
Decrease in Agricultural Productivity	Reduction in crop yields for major agricultural products including field crops and tree products due to changing temperature and precipitation patterns, extreme weather, loss of pollinators, saltwater intrusion, and others.	Moderate	Potential	Extreme
Economic Losses from Commercial Structure Damage and Business Interruptions	Reduction in economic outputs during closures resulting from flooding and storm damage to places of business, as well as reductions in economic output due to extreme weather shutdowns, utility and infrastructure disruptions, and climate-driven supply chains issues.	Minimal	Potential	Moderate
Damage to Tourist Attractions and Recreation Amenities	Changes to revenues in the tourism and recreation industry, particularly those associated with distinct New England seasons (e.g., winter recreation, foliage viewing, recreational fishing) and tourism related to vulnerable historical landmarks.	Minimal	Potential	Minimal

Note: Decrease in Marine Fisheries and Aquaculture Productivity is not a significant impact in this region.

Boston Harbor Region Climate Impacts

The Commonwealth is already experiencing climate change impacts. The Boston Harbor region is particularly vulnerable to climate hazards such as increasing temperatures, sea level rise, storm surge, and more extreme precipitation. An understanding of the current and future impacts of climate change allows community decision-makers to best tailor adaptation plans to meet the specific challenges faced in this region. This report summarizes the highest urgency climate impacts across Human, Infrastructure, Natural Environment, Governance, and Economy sectors for the Boston Harbor region.

The highest urgency impacts are based on a review of the latest climate data developed for Massachusetts and a statewide assessment of potential climate impacts, informed by expert analysis and stakeholder engagement. The prioritized list will be an important input to the 2023 State Hazard Mitigation and Climate Adaptation Plan.

Regional Overview

Geography and Demographics*

- 18 cities and towns
- 1,623,600 people
- 51% minority
- 27% low-income
- 10% households with limited English language proficiency

Resources and Assets

- 384,000 residential properties
- 17,000 commercial properties
- 9,000 miles of road
- 2,000 acres of high marsh
- 18 miles of marine beaches

**For definitions of these demographic terms, please see Volume II of this report.*

Regional Climate Outlook

2030	2050	2070	2090
NEAR TERM The summer mean temperature could increase by 3.6°F from the historical period (1950-2013), worsening air quality.	**MID-CENTURY** Area affected by a 1 percent annual chance of a foot or more of coastal flooding increases by 3.6 times compared to current area.	**MID-LATE CENTURY** There could be 39 more days above 90°F, contributing to extreme heat health impacts.	**END OF CENTURY** Tropical cyclone frequency could increase by nearly 50 percent, leading to damage from storm surge, heavy rainfall, and high winds.

Most Urgent Impacts by Sector for the Boston Harbor Region

Including the City of Boston and 17 surrounding cities, this region is defined by dense population, economic activity, and coastal natural resources. Urban heat islands and coastal flooding drive many of the most urgent impacts. Below are the top two impacts per sector (additional impacts are listed for tied scores). The bookmark icons identify unique regional priorities, meaning for each sector, impacts that are not a top three most urgent impact statewide but are a top two impact regionally.

Human

Health and Cognitive Effects from Extreme Heat, including premature death and learning loss.

Health Effects from Degraded Air Quality, Emergency Service Response Delays and Evacuation Disruptions, and **Reduction in Food Safety and Security** (tie scores).

Infrastructure

Damage to Rails and Loss of Rail/ Transit Service, including flooding and track buckling during high heat events.

Loss of Urban Tree Cover due to heat, drought, and increased pests.

Natural Environment

Marine Ecosystem Degradation because of warming, particularly in the Gulf of Maine, and ocean acidification.

Freshwater Ecosystem Degradation due to warming waters and increased runoff.

Governance

Reduction in State and Municipal Revenues, including a reduced property tax base due to coastal flood risk.

Increase in Demand for State and Municipal Government Services, including emergency response, food assistance, and state-sponsored health care.

Economy

Reduction in the Availability of Affordably Priced Housing from direct damage (e.g., flooding) and the scarcity caused by increased demand.

Economic Losses from Commercial Structure Damage and Business Interruptions from flooding and storm damage, and climate-driven supply chain issues.

Featured Adaptation Effort

Heat Resilience Solutions for Boston

The City of Boston developed a comprehensive heat preparedness plan and implementation roadmap outlining a wide variety of strategies for addressing extreme heat, ranging from pop-up cooling stations to proposed zoning revisions to support cooler neighborhoods.

This Massachusetts Climate Change Assessment (Climate Assessment) evaluates a broad range of climate change risks to the Commonwealth, including impacts on human health, natural resources, and public and private assets. The Climate Assessment will serve as a core component of the 2023 update to the State Hazard Mitigation and Climate Adaptation Plan (SHMCAP), specifically concerning the detailed hazard risk assessment. The outputs of the Climate Assessment are designed to meet the requirements for State Hazard Mitigation Planning documents, and to directly inform and provide a risk prioritization focus to the Mitigation Strategy.

The Climate Assessment evaluates **impacts** from **climate stressors** (temperature, precipitation, sea level rise, etc.) and **climate hazards** (extreme heat, flooding, droughts, etc.) across five **sectors** in the state. The Assessment identifies statewide priority impacts that require near-term adaptation action as well as regional priorities for **seven regions** of the Commonwealth.

This report provides regional detail on the impacts of climate change in the Boston Harbor region of Massachusetts. For more details on the methods used in this assessment, please refer to the Statewide Report.

Regional Context

Regional Character and Demographics

The Boston Harbor region encompasses the Commonwealth's largest urban center. Despite being the smallest region by area, Boston Harbor is the second most populous and includes more than a third of the state's environmental justice block groups as designated by EEA. Boston Harbor is a key economic hub, featuring expanding employment opportunities, an increasingly competitive housing market, and the state's largest port. Healthcare and professional and technical services are fast-growing industries in the region, with construction, manufacturing, and other service industries also playing key roles.[51] This economic activity is supported by a dense network of transportation, communication, and energy infrastructure.

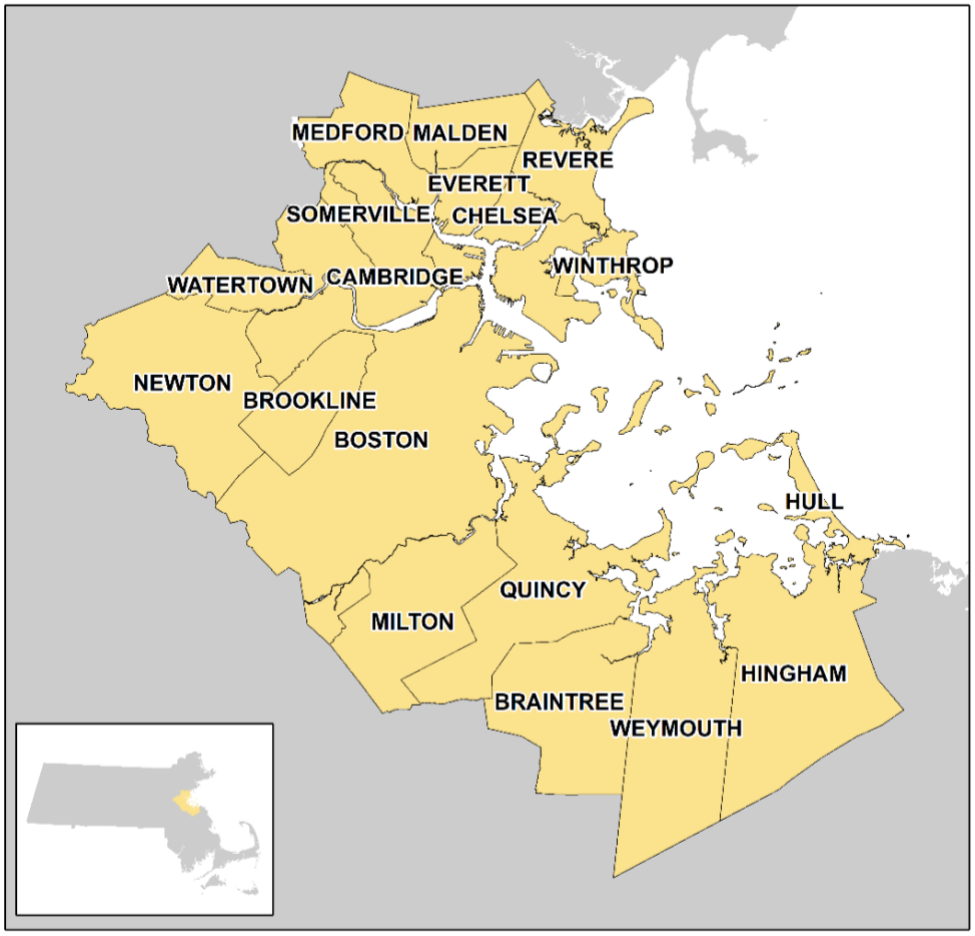
While Boston Harbor is primarily characterized by these urban features, the region's 18 cities and towns are also home to key natural resources. Nearly 2,000 acres of high marsh provide valuable ecosystem services, including coastal protection. The region's beaches, parks, and other green spaces provide recreational opportunities and much-needed stormwater infiltration capacity.

The Boston Harbor region boundary used for this assessment encompasses the Office of Coastal Zone Management's Boston Harbor region and overlaps with small segments of the North Shore and South Shore regions. The boundary includes the coastal areas of the Municipal Vulnerability Preparedness (MVP) program's Greater Boston region. Climate adaptation is a strong focus, with all 18 cities and towns engaged in climate vulnerability and resilience planning through the MVP Program.

[51] UMass Donahue Institute. Greater Boston Workforce Planning Blueprint. 2018. https://www.mass.gov/doc/greater-boston-workforce-planning-blueprint/download

Cities and Towns in the Boston Harbor Region

The MA Climate Change Assessment's Boston Harbor region includes these 18 cities and towns.



Highlights of Future Climate Projections

The most important climate hazards for the region include temperature extremes and changes to coastal hazards, including coastal flooding and the potential for hurricane force winds. Temperature changes affect air quality, human health, and road and rail infrastructure. Coastal hazards can affect built infrastructure, rapid transit and mobility overall, emergency service response times, and the incidence of injuries and death. Some key findings of the climate change projections that may be important for this region over the 21st century include the following:

2030	2050	2070	2090
NEAR TERM	MID-CENTURY	MID-LATE CENTURY	END OF CENTURY
The summer mean temperature could increase by 3.6°F from the historical period (1950-2013), worsening air quality.	Area affected by a 1 percent annual chance of a foot or more of coastal flooding increases by 3.6 times compared to current area.	There could be 39 more days above 90°F, contributing to extreme heat health impacts.	Tropical cyclone frequency could increase by nearly 50 percent, leading to damage from storm surge, heavy rainfall, and high winds.

Urgent Impacts in the Boston Harbor Region

Table 25 presents the two most urgent impacts per sector for the Boston Harbor region (more than two impacts are listed in the case of ties). The sections that follow provide additional details on the regional rankings for each sector. For more details on all impact assessment methodologies, see Chapter 2 of Volume II, the Statewide Report.

Table 25. Most Urgent Impacts by Sector for the Boston Harbor Region

Human Sector

- **Health and Cognitive Effects from Extreme Heat**, including premature death, and learning loss
- **Health Effects from Degraded Air Quality**, **Emergency Service Response Delays and Evacuation Disruptions**, and **Reduction in Food Safety and Security** (tie scores).

Infrastructure Sector

- **Damage to Rails and Loss of Rail/Transit Service**, including flooding and track buckling during high heat events.
- **Loss of Urban Tree Cover** due to heat, drought, and increased pests.

Natural Environment Sector

- **Marine Water Ecosystem Degradation** because of warming, particularly in the Gulf of Maine, and ocean acidification.
- **Freshwater Ecosystem Degradation** due to warming waters and increased runoff.

Governance Sector

- **Reduction in State and Municipal Revenues,** including a reduced property tax base due to coastal flood risk.
- **Increase in Demand for State and Municipal Government Services**, including emergency response, food assistance, and state-sponsored health care.

Economy Sector

- **Reduction in the Availability of Affordably Priced Housing** from direct damage (e.g., flooding) and the scarcity caused by increased demand.
- **Economic Losses from Commercial Structure Damage and Business Interruptions** from flooding and storm damage climate-driven supply chains issues.

Human Sector Impacts

With more than 1.6 million residents, the Boston Harbor region is projected to experience some of the most significant Human sector impacts in the state. Health and Cognitive Effects from Extreme Heat is the most urgent impact in the region. Projected increases in the frequency of extreme heat events couple with the region's high population density produce rates of temperature-related premature mortality that are 30 to 50 percent higher than the statewide average. Currently, six annual premature deaths are attributable to extreme temperature in the Boston Harbor region, but approximately 130 additional premature deaths per year are expected due to climate change by the end of the century, which accounts for over 30 percent of projected statewide heat impacts.[52] This estimate assumes that there would be no or limited further adaptation to extreme temperatures beyond those in place during the baseline period (1999-2001). These impacts are unevenly distributed—linguistically isolated populations, minority populations, and low-income populations are respectively 17 percent, 18 percent, and 22 percent more likely to die prematurely because of extreme heat in the region compared to the rest of the population. Other outcomes of extreme heat including learning loss in schools, increased emergency department visits, and occupational injuries. Efforts to adapt to heat effects in the region are ahead of most other parts of the state, but given the significant potential effects, further coordination is needed.

Other impacts in the Human sector are also projected to be significant in the region. One of the largest food distribution centers in Massachusetts is located in Everett and sits the 100-year floodplain of the Mystic River, where it may be vulnerable to flooding, potentially interrupting food supply chains (Reduction in Food Safety and Security). The region's coastal location, high population density, and high proportion of residents reliant on public transportation pose challenges for evacuations and emergency response (Emergency Service Response Delays and Evacuation Disruptions). Increased ozone and PM concentrations from climate change are projected to cause 430 additional childhood asthma diagnoses and more than 70 premature deaths among the population aged 65-plus annually by 2090 (Health Effects from Degraded Air Quality).[53] All three of these impacts are expected to have major magnitudes of consequence, disproportionate impacts, and a need for increased adaptation action.

[52] See Statewide report for more details. Estimates derived from application of Mills, D., Schwartz, J., Lee, M., Sarofim, M., Jones, R., Lawson, M., Duckworth, M., and Deck, L. (2014). Climate change impacts on extreme temperature mortality in select metropolitan areas in the United States. Climatic Change, 131, 83-95.
[53] See Statewide report for more details. Estimates derived from application of Fann, N., C. Nolte, M. Sarofim, J. Martinich, and N. Nisokolas (2021). Associations between simulated future changes in climate, air quality, and human health. JAMA Network Open, doi:10.1001/jamanetworkopen.2020.32064

Table 26. Boston Harbor Urgency Rankings for Human Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Health and Cognitive Effects from Extreme Heat	Impacts of extreme heat episodes on health, learning, and workplace injuries - covers all health aspects of changes in frequency and severity of days with extreme temperatures.	Extreme	Disproportionate	Moderate
Health Effects from Degraded Air Quality	Impacts of climate-induced changes in ambient and indoor air quality on health (e.g., loss of life, health care costs, missed school). Focused on changes from the direct impact of climate on particulate matter and ozone air quality, and the resulting health effects associated with these pollutants.	Major	Disproportionate	Moderate
Emergency Service Response Delays and Evacuation Disruptions	Extreme storms cause delays in response time, potentially leading to loss of life. Extreme coastal storm surge events and inland flooding could flood evacuation routes, trapping residents, leading to increased loss of life and injuries.	Major	Disproportionate	Moderate
Reduction in Food Safety and Security	Temperature increases, spoilage, and power outages can lead to increased food contamination. Changes in food production and supply chain disruption linked to climate change will worsen existing food insecurity.	Major	Disproportionate	Moderate
Increase in Vector Borne Diseases Incidence and Bacterial Infections	Increase in incidence of West Nile Virus, Lyme disease, and other diseases, and associated fatal and nonfatal outcomes, as a result of changes in temperature and an extended seasons for vectors and/or impact on bacterial loads.	Major	Potential	Moderate
Increase in Mental Health Stressors	Negative effects of weather and climate change on mental health, including a broad range of impacts on overall well-being associated mostly with temperature stress.	Major	Potential	Moderate
Damage to Cultural Resources	Climate stressors can damage important cultural resources that hold special value to residents of the Commonwealth.	Major	Potential	Moderate
Health Effects from Aeroallergens and Mold	Impacts from extended pollen seasons, particularly on people with asthma or hay fever, and increases in exposure to mold spores associated with more frequent flood events and higher humidity conditions.	Minimal	Potential	Moderate
Health Effects of Extreme Storms and Power Outages	Power outages and flooding, which could increase with more frequent extreme events, lead to a range of morbidity and sometimes fatal health outcomes and an increase in requests for emergency services.	Moderate	Limited	Moderate

Infrastructure Sector Impacts

Damage to Rails and Loss of Rail/Transit Service is the most urgent Infrastructure sector impact in the region. For the Boston Harbor portion of commuter and freight rail lines, rail repair costs in response to extreme heat deforming rails are the second largest among regions in the state,[54] behind only the Eastern Inland region. Rapid rail transit, including subway and trolley systems, is also key in the region. A recent study investigated measures of system resilience for the MBTA's rail rapid transit system and found that the combined effects of sea level rise and increased coastal storm frequency could render significant portions of the network inoperable, with projected interruptions becoming more widespread and severe later in the century.[55] Recent surveys have established that the rapid transit system is disproportionately relied on by EJ populations, with 29 percent of ridership among low-income groups and 34 percent among minority classifications,[56] implying that impacts to the system could present a disproportionate burden on these groups.

Loss of Urban Tree Cover is another significant and disproportionately distributed impact in the Boston Harbor region. Climate change is projected to stress urban trees through increased extreme event frequency, increased threat from pests, and reduced water and soil quality, leading to more frequent tree mortality and higher management costs. Projected temperature increases and the urban heat island effect make tree coverage particularly valuable in a large urban center like the Boston metro area, which also features a high density of EJ block groups. This is a significant area of adaptation focus in the region currently. Other impacts in this sector are projected to be either smaller in magnitude or less disproportionate. For example, though the magnitude of Damage to Coastal Buildings and Ports is projected to be extreme, the impacts are primarily concentrated outside of EJ block groups.

Table 27. Boston Harbor Urgency Rankings for Infrastructure Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Damage to Rails and Loss of Rail/Transit Service	Extreme temperature events reduce useful life of track and cause buckling events, which also lead to indirect impacts from delays that occur due to track buckling and repair. Also addressed are effects of storms and sea level rise on subway and commuter rail operation.	Major	Disproportionate	Moderate

[54] See Statewide report for more details. Estimates derived from application of Neumann, J.E., Chinowsky, P., Helman, J., Black, M., Fant, C., Strzepek, K., and Martinich, J. (2021) Climate effects on US infrastructure: the economics of adaptation for rail, roads, and coastal development. Climatic Change 167, 44 (2021). https://doi.org/10.1007/s10584-021-03179-w

[55] Martello, M.V., Whittle, A.J., Keenan, J.M. and Salvucci, F.P., 2021. Evaluation of climate change resilience for Boston's rail rapid transit network. Transportation Research Part D: Transport and Environment, 97, p.102908, https://doi.org/10.1016/j.trd.2021.102908

[56] See MBTA 2015–17 Systemwide Passenger Survey, published May 2018 available at: https://www.ctps.org/dv/mbtasurvey2018/2015_2017_Passenger_Survey_Final_Report.pdf

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Loss of Urban Tree Cover	Urban trees are susceptible to invasive pests and high heat/drought conditions and provide many services including mitigating heat island effects, pollution removal, etc.	Major	Disproportionate	Minimal
Damage to Electric Transmission and Distribution Infrastructure	Costs to repair transmission infrastructure failure associated with heat stress and extreme events that directly affect the transmission and distribution system. Includes wired communication and information technology systems.	Major	Potential	Moderate
Reduction in Clean Water Supply	Addresses changes in water quantity and quality for water supplied for all human uses. Changes in precipitation patterns and saltwater intrusion can lead to impaired surface and groundwater supply available for municipal, industrial, commercial, and agricultural uses.	Minimal	Disproportionate	Moderate
Damage to Coastal Buildings and Ports	Sea level rise, coastal erosion, and storm surge, as well as high wind events from tropical and extra-tropical storms, will cause increased damage to coastal structures, land, and related infrastructure such as ports and marinas.	Extreme	Limited	Moderate
Increased Risk of Dam Overtopping or Failure	Climate change could lead to more frequent overtopping of some, or all of the state dam safety program designated High or Significant Hazard dams, causing flooding of downstream areas.	Moderate	Potential	Minimal
Damage to Inland Buildings	Addresses the risk of flooding to inland structures from rainfall (pluvial flooding) when drainage systems are overwhelmed by large rainstorms and rivers (fluvial flooding).	Moderate	Limited	Moderate
Damage to Roads and Loss of Road Service	Damage to roads from extreme precipitation, flooding, and temperature increases the need for repair and maintenance, and indirect effects of increased vehicle operating costs from driving on roads in poor condition. Includes effects on bridges and culverts at road crossings.	Moderate	Limited	Moderate
Loss of Energy Production and Resources	Changes in temperature increase electricity demand and reduce production efficiency, requiring changes in the overall network cost of meeting electric demand. Effects on solar energy production potentially subject to flooding are also considered.	Minimal	Limited	Minimal

Natural Environment Sector Impacts

While Boston Harbor is largely urban, nearby natural resources play a significant cultural and economic role in the region. Projected climate changes represent a significant departure from

existing conditions and have the potential to exacerbate coastal storm impacts and cause systemic disruptions to the region's ecosystems. Increases in sea surface temperature can alter weather patterns and storm tracks and force marine species beyond their historic range in search of suitable habitat. Ocean acidification related to increasing CO_2 concentrations further threatens marine habitats and species. Freshwater ecosystems are at risk from increased nutrient loading and harmful algal bloom growth, increased contaminant concentrations during drought conditions, and shifting habitat regimes as air and water temperatures rise. Adaptation around the threats to both marine and freshwater ecosystems is lagging compared with the action needed to respond to these challenges. Focus on this area has increased in recent years, though—in 2021, the Massachusetts Special Legislative Commission on Ocean Acidification published the Report on the Ocean Acidification Crisis in Massachusetts, which includes specific recommendations to mitigate and adapt to ocean acidification. Still, further coordination, research, and action is needed. Wetlands and beaches play a role in protecting coastal communities and infrastructure in the region. Sea level rise, acidification, and increases in storm frequency and intensity threaten these resources and make them all the more important to preserve.

Table 28. Boston Harbor Urgency Rankings for Natural Environment Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Marine Water Ecosystem Degradation	Changing sea surface temperatures, ocean acidification, and increased runoff nearshore alter habitat conditions in marine environments (including submerged aquatic vegetation) leading to changing marine species distribution.	Extreme	Potential	Extreme
Freshwater Ecosystem Degradation	Rising temperature and changing precipitation patterns will lead to a reduction in water quality and changes in water quantity, resulting in changes to habitat quality in rivers, streams, ponds, lakes, and freshwater wetlands.	Major	Potential	Extreme
Shifting Distribution of Native and Invasive Species	Changing climatic conditions shift suitable habitat for native species (flora and fauna) and increases competition with invasive species, potentially causing losses in biodiversity and loss of culturally important species.	Major	Potential	Moderate
Coastal Wetland Degradation	Climate impacts such as increased temperatures, increased runoff/precipitation, invasive species and drought act as stressors to coastal wetland environments. When considering coastal wetland degradation on a regional scale, sea level rise leads to the highest degree of habitat shifts and possible loss of salt marshes and important ecosystem services.	Major	Potential	Moderate

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Forest Health Degradation	Warming temperatures, changing precipitation, increasing pest occurrence, more frequent and intense storms, and increased wildfire risk may cause a decline in forest health (e.g., biodiversity, biomass, resiliency) along with the loss of carbon sequestration and other ecosystem services. Impacts vary by forest type.	Moderate	Potential	Moderate
Soil Erosion	Increase in extreme precipitation results in increased erosion and loss of vegetation or changes in vegetation type, particularly along riverbanks but also in forests and in a number of landscapes.	Minimal	Potential	Moderate
Coastal Erosion	Climate change is expected to increase coastal erosion, primarily driven by sea level rise, particularly in areas not protected by wetlands (e.g., dunes, banks, beaches), which has consequences for water quality, land use, and habitat quality.	Minimal	Potential	Moderate

Governance Sector Impacts

Boston Harbor's most urgent Governance sector impacts are Increase in Demand for State and Municipal Government Services and Reduction in State and Municipal Revenues. Climate change effects across a range of other impacts could increase reliance on government services, driving up expenses. This could include increased needs for MassHealth (connected to both extreme heat and air quality health impacts), food security support (which would expand the need for state-level SNAP programs), and emergency response as a result of climate change (particularly connected to impassable roads during extreme coastal storm events or more routine "high-tide" or "sunny-day" flooding of critical road infrastructure). Similarly, long-term climate impacts on municipal tax bases, are a potentially significant risk that is not well characterized in the available literature. Many of these impacts can be expected to be concentrated among those residing in EJ-designated block groups. Climate migration could also impact the region—Hauer et al. (2020) predict that Massachusetts is home to anywhere between 300 to 500 thousand individuals that may be vulnerable to displacement due to sea level rising, either because they reside in low elevation coastal zones or in the 100-year projected floodplain.[57]

[57] Hauer, M.E., Fussell, E., Mueller, V. et al (2020). Sea-level rise and human migration. Nat Rev Earth Environ 1**,** 28–39. https://doi.org/10.1038/s43017-019-0002-9

Table 29. Boston Harbor Urgency Rankings for Governance Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Reduction in State and Municipal Revenues	State and municipal revenue streams impacted through property tax loss following structure damage of any type, from any hazard, and sales tax losses associated with business interruptions or effects on industrial activities.	Major	Disproportionate	Moderate
Increase in Demand for State and Municipal Government Services	Climate change serves as a threat multiplier, which can increase the need for expenditures to meet existing government service. Examples include capital, equipment, or operating costs for emergency response provision and state sponsored health programs.	Major	Potential	Moderate
Increase in Costs of Responding to Climate Migration	Costs and stresses to governments accommodating and/or preparing for forced and voluntary human migration of populations in response to climate threats or related economic pressures. Includes intra-state, inter-state, and international in- and out-migration, and is generally more abrupt than routine population changes in response to non-climate stressors (such as economic development or decline).	Minimal	Potential	Moderate
Damage to Coastal State and Municipal Buildings and Land	Risk to vulnerable state and municipal owned structures and other property from coastal flooding, wind, extreme heat, and extreme storms. Includes damage repair costs and service losses during closures.	Major	Limited	Moderate
Increase in Need for State and Municipal Policy Review and Adaptation Coordination	State agencies and municipalities may require additional full-time employees and specialized training to meet the challenges of climate change. Specifically, state and municipal staff will need capacity to provide adaptation planning support and to review and modify policies in response to changing conditions and uncertainty associated with climate change.	Minimal	Potential	Moderate
Damage to Inland State and Municipal Buildings and Land	Risk to vulnerable state and municipal owned structures and other property from flooding, extreme heat, and extreme storms. Includes damage repair costs and service losses during closures.	Minimal	Limited	Moderate

Economy Sector Impacts

The current need for affordably priced housing is acute in the Boston Harbor region, which has the most expensive housing costs in the Commonwealth. This region is home to a large number of federally subsidized affordable housing units vulnerable to coastal flood risk, with a high concentration of units affected by 2050 in Boston (3,189 units exposed per year), Quincy (668 units), Cambridge (510 units), and Revere (266 units). These four cities are ranked in the top 20

cities nationally for this metric, and Boston is third in the nation in expected number of exposed affordable housing units, trailing New York and Atlantic City.[58] These coastal flood threats and higher construction costs needed to increase building resilience may limit the availability of affordably priced housing.

Similar challenges from flooding and storm damage exist for businesses in the Boston Harbor region, which is home to the largest economic hub in the Commonwealth. Business closures and direct damages to commercial structures are of particular concern for Boston Harbor, which accounts for approximately 89 percent of the estimated annual statewide direct damages to the commercial and industrial properties in projections through the end of the century.[59] Flood-related indirect costs from business interruptions in the region are projected to increase by more than $750 million by 2050.[60] Nationally estimated potential impacts of climate change on supply chains and the resulting impact on business activity would also likely be found in this region, in part because of the potential for hurricanes to damage goods entry locations such as the South Boston container port, and more generally because of the Boston areas high concentration of commercial and industrial activity. Reduced Ability to Work is also projected to have an extreme magnitude of consequence in the region, and adaptation actions outlined in municipal climate plans in the region start to address extreme temperature threats to high-risk workers.

Table 30. Boston Harbor Urgency Rankings for Economy Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Reduction in the Availability of Affordably Priced Housing	An increase in demand for housing that is affordable and a decrease in supply worsens the scarcity of affordably priced housing. Demand for housing that is affordable can result if people are forced to relocate either due to direct damage to existing housing or because of climate-related economic pressures. The supply of affordably priced housing is reduced due to direct physical damage from climate impacts and potentially higher construction costs to increase resilience to threats from climate change.	Extreme	Disproportionate	Moderate

[58] Buchanan, M.K., Kulp, S., Cushing, L., Morello-Frosch, R., Nedwick, T. and Strauss, B., 2020. Sea level rise and coastal flooding threaten affordable housing. Environmental Research Letters, 15(12).

[59] See Statewide report for more details. Estimates derived from application of MC-FRM flood risk and Neumann, J. E., Chinowsky, P., Helman, J., Black, M., Fant, C., Strzepek, K., & Martinich, J. 2021. Climate effects on US infrastructure: the economics of adaptation for rail, roads, and coastal development. Climatic Change. https://doi.org/10.1007/s10584-021-03179-w.

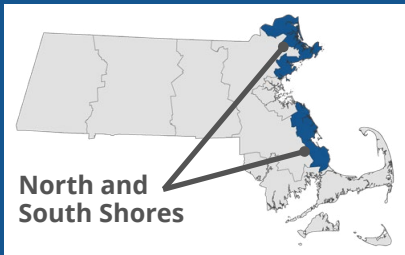
[60] First Street Foundation and Arup. 2021., The 4th National Risk Assessment: Climbing Commercial Closures. December 13, 2021, available at: https://firststreet.org/research-lab/published-research/article-highlights-from-climbing-commercial-closures/. Additional methodological information available in Porter, Jeremy R., Using a High-Precision Flood Risk Assessment Tool to Understand Commercial Building and Market Impacts in the United States (December 8, 2021). Available at SSRN: https://ssrn.com/abstract=3981118 or http://dx.doi.org/10.2139/ssrn.3981118

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Economic Losses from Commercial Structure Damage and Business Interruptions	Reduction in economic outputs during closures resulting from flooding and storm damage to places of business, as well as reductions in economic output due to extreme weather shutdowns, utility and infrastructure disruptions, and climate-driven supply chains issues.	Extreme	Potential	Extreme
Reduced Ability to Work	More frequent extreme heat days leads to lost wages and decreased productivity, as do increasing incidence of climate-induced health effects (e.g., asthma, allergies, vector borne disease, extreme heat). Weather-induced disruptions to transportation and ability to work may also lead to lost wages and worker productivity. Impacts are felt most by workers in outdoor industries, those who rely on public transportation, and those who care for others at home.	Extreme	Potential	Moderate
Decrease in Marine Fisheries and Aquaculture Productivity	Changes in water temperature regimes and acidification in the marine environment change fish habitat and alter commercial landings and revenue, including effects on related industries.	Minimal	Disproportionate	Moderate
Damage to Tourist Attractions and Recreation Amenities	Changes to revenues in the tourism and recreation industry, particularly those associated with distinct New England seasons (e.g., winter recreation, foliage viewing), recreational fishing, beach recreation (i.e., reduction in beach width due to sea level rise and coastal erosion), and tourism related to vulnerable historical landmarks.	Moderate	Disproportionate	Minimal
Decrease in Agricultural Productivity	Reduction in crop yields for major agricultural products including field crops and tree products due to changing temperature and precipitation patterns, extreme weather, loss of pollinators, saltwater intrusion, and others.	Minimal	Potential	Insignificant

North and South Shores Region Climate Impacts

The Commonwealth is already experiencing climate change impacts. The North and South Shores region is particularly vulnerable to climate hazards such as increasing temperatures, sea level rise, storm surge, and more extreme precipitation. An understanding of the current and future impacts of climate change allows community decision-makers to best tailor adaptation plans to meet the specific challenges faced in this region. This report summarizes the highest urgency climate impacts across Human, Infrastructure, Natural Environment, Governance, and Economy sectors for the North and South Shores region.

The highest urgency impacts are based on a review of the latest climate data developed for Massachusetts and a statewide assessment of potential climate impacts, informed by expert analysis and stakeholder engagement. The prioritized list will be an important input to the 2023 State Hazard Mitigation and Climate Adaptation Plan.



Regional Overview

Geography and Demographics*

- 32 cities and towns
- 731,000 people
- 25% minority
- 20% low-income
- 4% households with limited English language proficiency

Resources and Assets

- 243,800 residential properties
- 9,600 commercial properties
- 9,600 miles of road
- 21,500 acres of high marsh
- 375,000 acres of forest

**For definitions of these demographic terms, please see Volume II of this report.*

Regional Climate Outlook

2030	2050	2070	2090
NEAR TERM The summer mean temperature could increase by 3.6°F from the historical period (1950-2013), causing impacts to local agriculture.	**MID-CENTURY** Area affected by a 5 percent annual chance of a foot or more of coastal flooding increases by nearly two times compared to current area.	**MID-LATE CENTURY** Sea surface temperatures could increase by 5°F, reducing marine fish catch and increasing risks from harmful bacterial infections.	**END OF CENTURY** Tropical cyclone frequency in the coastal New England region could increase by nearly 50 percent, leading to damage from storm surge, heavy rainfall, and high winds.

Most Urgent Impacts by Sector for the North and South Shores Region

This region is characterized by its coastal economy, infrastructure, and natural resources. Local governments are tasked with maintaining services while facing potential revenue losses from threats to coastal properties. Below are the top two impacts per sector (three listed for tied scores). The bookmark icons identify unique regional priorities, meaning for each sector, impacts that are not a top three most urgent impact statewide but are a top impact regionally.

Human

Emergency Service Response Delays and Evacuation Disruptions during coastal storm surge events and inland floods.

Health Effects from Degraded Air Quality, including childhood asthma cases and premature death due to the climate impact on particulate matter and ozone air quality.

Reduction in Food Safety and Security due to production and supply chain issues, as well as spoilage during power outages.

Infrastructure

Damage to Electric Transmission and Utility Distribution Infrastructure associated with heat stress and extreme events.

Damage to Coastal Buildings and Ports from sea level rise and storm surge, coastal erosion, and high winds.

Natural Environment

Marine Ecosystem Degradation because of warming, particularly in the Gulf of Maine, and ocean acidification.

Coastal Wetland Degradation from sea level rise and storm surge.

Governance

Increase in Demand for State and Municipal Government Services, including emergency response, food assistance, and state-sponsored health care.

Reduction in State and Municipal Revenues, including a reduced property tax base due to coastal flood risk.

Increase in Costs of Responding to Climate Migration, including planning for abrupt changes in local populations.

Economy

Reduction in the Availability of Affordably Priced Housing from direct damage (e.g., flooding) and the scarcity caused by increased demand.

Reduced Ability to Work, particularly for outdoor workers during extreme heat, as well as commute delays due to damaged infrastructure.

Featured Adaptation Effort

Peabody-Salem Resilient North River Corridor & Riverwalk Project

In Peabody and Salem, the North River Canal restoration project has installed and will continue to install elevated river walkways, rain gardens, and other recreational amenities. This work will improve flood resilience along this tidal river.

Photo: City of Salem

This Massachusetts Climate Change Assessment (Climate Assessment) evaluates a broad range of climate change risks to the Commonwealth, including impacts on human health, natural resources, and public and private assets. The Climate Assessment will serve as a core component of the 2023 update to the State Hazard Mitigation and Climate Adaptation Plan (SHMCAP), specifically concerning the detailed hazard risk assessment. The outputs of the Climate Assessment are designed to meet the requirements for State Hazard Mitigation Planning documents, and to directly inform and provide a risk prioritization focus to the Mitigation Strategy.

The Climate Assessment evaluates **impacts** from **climate stressors** (temperature, precipitation, sea level rise, etc.) and **climate hazards** (extreme heat, flooding, droughts, etc.) across five **sectors** in the state. The Assessment identifies statewide priority impacts that require near-term adaptation action as well as regional priorities for **seven regions** of the Commonwealth.

This report provides regional detail on the impacts of climate change in the North and South Shores region of Massachusetts. For more details on the methods used in this assessment, please refer to the Statewide Report.

Regional Context

Regional Character and Demographics

The North and South Shores region includes 32 coastal municipalities flanking the Greater Boston area. The two areas north and south of Boston are grouped together in this region because, although they each have distinct characteristics, the hazards faced and populations and resources exposed are similar. Around ten percent of the state population live in the region, which is made up of mostly mid-sized cities and towns. Lynn is the region's largest city, with just over 100,000 residents, and it also includes a high density of designated environmental justice block groups. In total, the region has less than seven percent of the state's environmental justice block groups. The blue economy (meaning economic activity around sustainable ocean resources use) plays a growing role in the region, though the main economic drivers continue to be healthcare, professional services, manufacturing, and finance.[61,62]

The North and South Shores have more coastal wetland area than any other region, with nearly 24,000 acres of high and low marsh, and the region also features more than 38 miles of marine beach. These coastal areas and the marine ecosystems off the coast are key resources in the region, stimulating the regional economy, providing local food sources, protecting coastal people and infrastructure, and carrying significant cultural value.

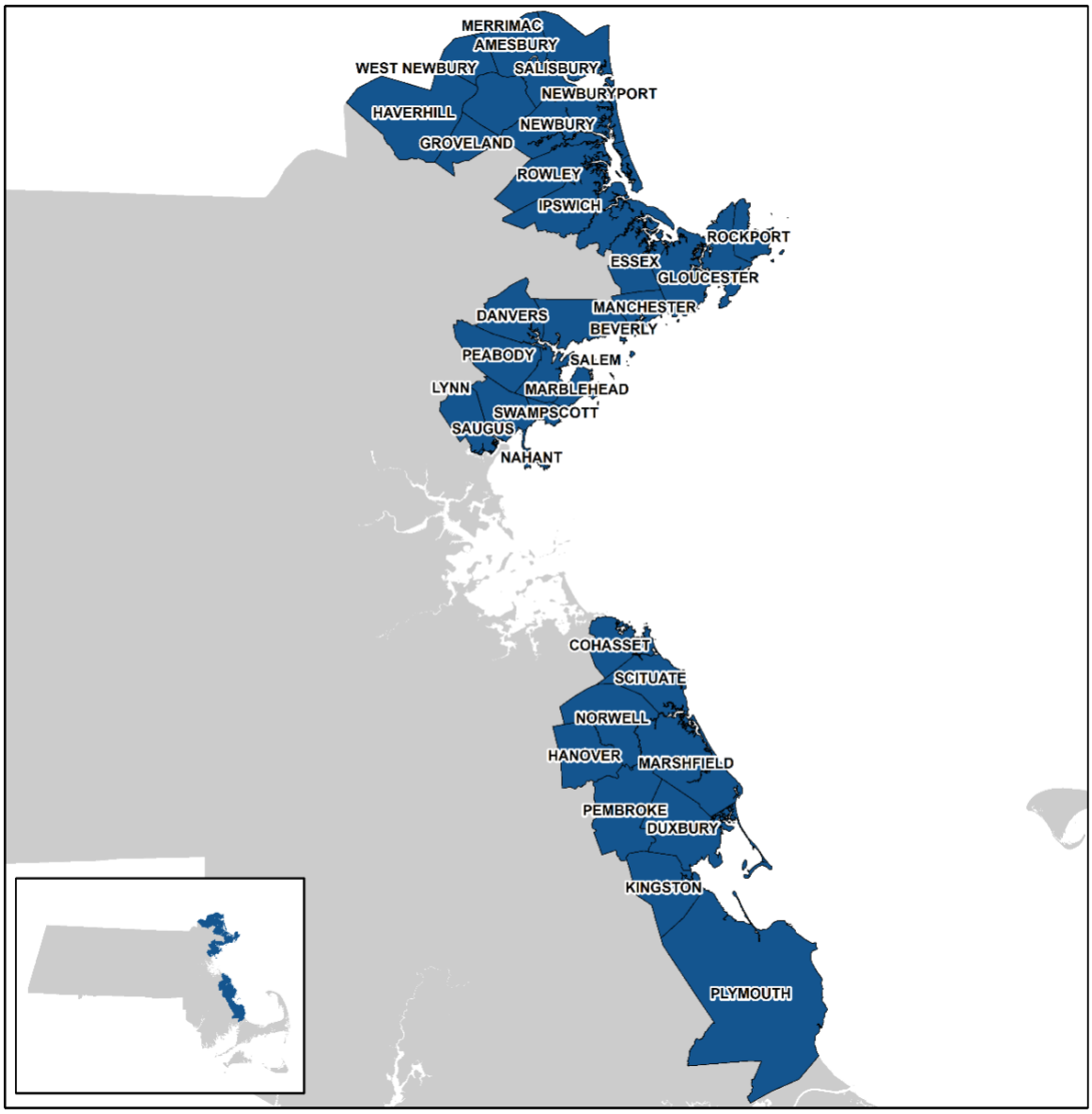
[61] Greater Lowell Workforce Development Board, North Shore Workforce Investment Board, Merrimack Valley Workforce Development Board. 2018. Northeast Labor Market Blueprint. https://www.mass.gov/doc/northeast-regional-workforce-skills-planning-initiative-regional-blueprint/download

[62] Southeastern Massachusetts Workforce Development Team. 2018. Southeastern Massachusetts Labor Market Blueprint. https://www.mass.gov/doc/southeast-regional-workforce-skills-planning-initiative-regional-blueprint/download

As of the FY2023 MVP grant round, all the region's municipalities are actively engaged in climate resilience planning and adaptation action through the MVP program.

Cities and Towns in the Climate Assessment's North and South Shores Region

The MA Climate Change Assessment's North and South Shores region includes these 32 cities and towns.



Highlights of Future Climate Projections

The most important climate hazards for this region include changes to coastal hazards, including sea surface temperature changes, coastal flooding, and the potential for hurricane force winds from both tropical and extratropical storms; and flooding associated with high rainfall events. Coastal hazards can affect built infrastructure, marine fisheries productivity, emergency service response times and evacuation routes, and the incidence of injuries. Some

key findings of the climate change projections that may be important for this region over the 21st century include the following:

2030	2050	2070	2090
NEAR TERM	MID-CENTURY	MID-LATE CENTURY	END OF CENTURY
The summer mean temperature could increase by 3.6°F from the historical period (1950-2013), causing impacts to local agriculture.	Area affected by a 5 percent annual chance of a foot or more of coastal flooding increases by nearly two times compared to current area.	Sea surface temperatures could increase by 5°F, reducing marine fish catch and increasing risks from harmful bacterial infections.	Tropical cyclone frequency in the coastal New England region could increase by nearly 50 percent, leading to damage from storm surge, heavy rainfall, and high winds.

Urgent Impacts in the North and South Shores Region

Table 31 presents the two most urgent impacts per sector for the North and South Shores region (more than two impacts are listed in the case of ties). The sections that follow provide additional details on the regional rankings for each sector. For more details on all impact assessment methodologies, see Chapter 2 of Volume II, the Statewide Report.

Table 31. Two Most Urgent Impacts by Sector for the North and South Shores Region

Human Sector

- **Emergency Service Response Delays and Evacuation Disruptions** during coastal storm surge events and inland floods.
- **Health Effects from Degraded Air Quality**, including childhood asthma cases and premature death due to the climate penalty on particulate matter and ozone air quality.
- **Reduction in Food Safety and Security** due to production and supply chain issues, as well as spoilage during power outages.

Infrastructure Sector

- **Damage to Electric Transmission and Distribution Infrastructure** associated with heat stress and extreme events.
- **Damage to Coastal Buildings and Ports** from sea level rise and storm surge, coastal erosion, and high winds.

Natural Environment Sector

- **Marine Ecosystem Degradation** because of warming, particularly in the Gulf of Maine, and ocean acidification.
- **Coastal Wetland Degradation** from sea level rise and storm surge.

Governance Sector

- **Increase in Demand for State and Municipal Government Services**, including emergency response, food assistance, and state-sponsored health care.
- **Reduction in State and Municipal Revenues**, including reduced property tax base due to coastal flood risk.
- **Increase in Costs of Responding to Climate Migration**, including planning for abrupt changes in local populations.

Economy Sector

- **Reduction in the Availability of Affordably Priced Housing** from direct damage (e.g., flooding) and the scarcity caused by increased demand.
- **Reduced Ability to Work**, particularly for outdoor workers during extreme heat, as well as commute delays due to damaged infrastructure.

Human Sector Impacts

The North and South Shores regions are most at risk of Human sector impacts related to sea level rise flooding and the air quality effects of climate change. Over the next century, climate change is expected to increase coastal traffic delays due to roads becoming impassable during storm events due to the combined effects of sea level rise and storm surge events, which can lead to emergency service delays and evacuation disruptions. This issue is particularly concerning in areas of the North and South Shore region reliant on limited evacuation routes. Linguistically isolated, low income, and minority populations are respectively 14 percent, 15 percent, and 17 percent more likely to experience emergency response delays due to climate change in the North and South Shores region compared to the rest of the population,[63] making this impact highly disproportionate. Food distribution centers and transportation routes are particularly vulnerable to coastal flooding, and supply chain issues can result in unavailability of food. Food safety, particularly associated with spoilage and bacterial contamination, is also associated with high temperature events and risk of power outages.[64]

Air quality degradation is also a highly urgent impact in this region. Climate change worsens air quality via warmer temperatures increasing the rate of ground-level ozone formation, less frequent rain events reducing flushing of particulate matter, and increasing wildfire, both in Massachusetts and across North America. Currently, 2,900 annual new cases of childhood asthma and 200 annual premature deaths among older adults are attributable to impaired air quality in the North and South Shores region. One hundred and twenty additional new cases of childhood asthma are estimated in the region as a result of the impact of climate change by the end of the century. Thirty-five additional premature deaths among the population age 65-plus are estimated as a result of climate change in the North and South Shores region by the end of the century.[65]

Table 32. North and South Shores Urgency Rankings for Human Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Emergency Service	Extreme storms cause delays in response time, potentially leading to loss of	Major	Disproportionate	Moderate

[63] See Statewide report for detailed methods for estimating disproportionality. Estimates shown here are based on comparison of impacts regionwide among state designated EJ block groups compared to other block groups in the region.

[64] A potentially related effect on food security involves effects of more variable streamflow on freshwater fish guilds which may contribute to subsistence food stocks. There is some evidence of climate change potentially leading to a change in predominant fish species (see Jones, R., C. Travers, C. Rodgers, B. Lazar, E. English, J. Lipton, J. Vogel, K. Strzepek, and J. Martinich (2012). Climate change impacts on freshwater recreational fishing in the United States. *Mitigation and Adaptation Strategies for Global Change*, doi:10.1007/s11027-012-9385-3. Available online at https://link.springer.com/article/10.1007/s11027-012-9385-3), Unfortunately there is currently very limited evidence on the impact of those changes on fish available as food for subsistence.

[65] Fann, N., C. Nolte, M. Sarofim, J. Martinich, and N. Nisokolas (2021). Associations between simulated future changes in climate, air quality, and human health. *JAMA Network Open*, doi:10.1001/jamanetworkopen.2020.32064; and Tétreault L-F, Doucet M, Gamache P, Fournier M, Brand A, Kosatsky T, Smargiassi A. 2016. Childhood Exposure to Ambient Air Pollutants and the Onset of Asthma: An Administrative Cohort Study in Quebec. *Environmental Health Perspectives* 124(8):1276-1282.

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Response Delays and Evacuation Disruptions	life. Extreme coastal storm surge events and inland flooding could flood evacuation routes, trapping residents, leading to increased loss of life and injuries.			
Health Effects from Degraded Air Quality	Impacts of climate-induced changes in ambient and indoor air quality on health (e.g., premature loss of life, health care costs, missed school). Focused on changes from the direct impact of climate on particulate matter and ozone air quality, and the resulting health effects associated with these pollutants.	Major	Potential	Moderate
Reduction in Food Safety and Security	Temperature increases, spoilage, and power outages can lead to increased food contamination. Changes in food production and supply chain disruption linked to climate change will worsen existing food insecurity.	Minimal	Disproportionate	Moderate
Damage to Cultural Resources	Climate stressors can damage important cultural resources that hold special value to residents of the Commonwealth.	Moderate	Potential	Moderate
Increase in Mental Health Stressors	Negative effects of weather and climate change on mental health, including a broad range of impacts on overall well-being associated mostly with temperature stress.	Moderate	Potential	Moderate
Health Effects from Aeroallergens and Mold	Impacts from extended pollen seasons, particularly on people with asthma or hay fever, and increases in exposure to mold spores associated with more frequent flood events and higher humidity conditions.	Moderate	Potential	Moderate
Increase in Vector Borne Diseases Incidence and Bacterial Infections	Increase in incidence of West Nile Virus, Lyme disease, and other diseases, and associated fatal and nonfatal outcomes, as a result of changes in temperature and an extended seasons for vectors and/or impact on bacterial loads.	Major	Limited	Moderate
Health and Cognitive Effects from Extreme Heat	Impacts of extreme heat episodes on health, learning, and workplace injuries - covers all health aspects of changes in frequency and severity of days with extreme temperatures.	Major	Limited	Moderate
Health Effects of Extreme Storms and Power Outages	Power outages and flooding, which could increase with more frequent extreme events, lead to a range of morbidity and sometimes fatal health outcomes and an increase in requests for emergency services.	Moderate	Limited	Moderate

Infrastructure Sector Impacts

The most urgent impacts in the Infrastructure sector in the North and South Shores region are primarily driven by coastal flooding and storms. This region has the second highest (behind Boston Harbor region) costs of repair for Damage to Electric Transmission and Utility Distribution Infrastructure among regions in the Commonwealth. Available estimates could grow to an additional $8 million in 2030; $13 million annually in 2050; $25 million in 2070; and $37 million annually by 2090.[66] Damage to Coastal Buildings and Ports is the second most urgent impact. Current damages in this region from coastal floods on residential, commercial, and industrial properties are $25 million per year and are projected to grow an additional $15 million by 2030; $35 million by 2050; and $75 million by 2070.[67] Though economic damages are higher for coastal buildings and ports, the adaptation gap is smaller given the resources already focused on addressing this issue. Inland flooding does not rise to the top of the urgency ranking in this sector as it does statewide, however it still is projected to have a moderate level of consequence, though with limited disproportionate impact.

Table 33. North and South Shores Urgency Rankings for Infrastructure Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Damage to Electric Transmission and Utility Distribution Infrastructure	Costs to repair transmission infrastructure failure associated with heat stress and extreme events that directly affect the transmission and distribution system. Includes wired communication and information technology systems.	Major	Disproportionate	Extreme
Damage to Coastal Buildings and Ports	Sea level rise, coastal erosion, and storm surge, as well as high wind events from tropical and extra-tropical storms, will cause increased damage to coastal structures, land, and related infrastructure such as ports and marinas.	Major	Disproportionate	Moderate
Reduction in Clean Water Supply	Addresses changes in water quantity and quality for water supplied for all human uses. Changes in precipitation patterns and saltwater intrusion can lead to impaired surface and groundwater supply available for municipal, industrial, commercial, and agricultural uses.	Moderate	Disproportionate	Minimal
Loss of Urban Tree Cover	Urban trees are susceptible to invasive pests and high heat/drought conditions and provide many services including	Moderate	Disproportionate	Minimal

[66] Fant, C., Boehlert, B., Strzepek, K., Larsen, P., White, A., Gulati, S., Li, Y., & Martinich, J. (2020). Climate change impacts and costs to U.S. electricity transmission and distribution infrastructure. Energy, 195. Doi:10.1016/j.energy.2020.116899

[67] Neumann, J. E., Chinowsky, P., Helman, J., Black, M., Fant, C., Strzepek, K., & Martinich, J. 2021. Climate effects on US infrastructure: the economics of adaptation for rail, roads, and coastal development. Climatic Change. https://doi.org/10.1007/s10584-021-03179-w using MC-FRM flood data.

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
	mitigating heat island effects, pollution removal, etc.			
Damage to Roads and Loss of Road Service	Damage to roads from extreme precipitation, flooding, and temperature increases the need for repair and maintenance, and indirect effects of increased vehicle operating costs from driving on roads in poor condition. Includes effects on bridges and culverts at road crossings.	Major	Limited	Moderate
Loss of Energy Production and Resources	Changes in temperature increase electricity demand and reduce production efficiency, requiring changes in the overall network cost of meeting electric demand. Effects on solar energy production potentially subject to flooding are also considered.	Moderate	Limited	Moderate
Damage to Inland Buildings	Addresses the risk of flooding to inland structures from rainfall (pluvial flooding) when drainage systems are overwhelmed by large rainstorms and rivers (fluvial flooding).	Moderate	Limited	Moderate
Damage to Rails and Loss of Rail/Transit Service	Extreme temperature events reduce useful life of track and cause buckling events, which also lead to indirect impacts from delays that occur due to track buckling and repair. Also addressed are effects of storms and sea level rise on subway and commuter rail operation.	Minimal	Limited	Moderate
Increased Risk of Dam Overtopping or Failure	Climate change could lead to more frequent overtopping of some, or all of the state dam safety program designated High or Significant Hazard dams, causing flooding of downstream areas.	Minimal	Limited	Minimal

Natural Environment Sector Impacts

With nearly 40 miles of beaches and nearly 24,000 acres of saltwater marsh, the North and South Shore is defined by its marine and coastal natural resources. Impacts to marine ecosystems from increased temperatures, ocean acidification, and degradation of nearshore water quality are projected to have an extreme magnitude of consequence and have an extreme adaptation gap. The region is projected to experience near term gains in total salt marsh area (with regularly flooded marsh expanding at a faster rate than the projected loss of irregularly flooded marsh), though by the end of the century, the rate of irregularly flooded marsh loss accelerates, resulting in a net loss of about 63 percent of saltmarsh in the region by 2100. Though coastal resources are most prominent in the region, freshwater ecosystems and forests are also important to the natural environment in the region and face risks from climate change. These impacts are foundational to many other impacts and sectors in the region including human health and wellbeing and economic activity.

Table 34. North and South Shores Urgency Rankings for Natural Environment Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Marine Ecosystem Degradation	Changing sea surface temperatures, ocean acidification, and increased runoff nearshore alter habitat conditions in marine environments (including submerged aquatic vegetation) leading to changing marine species distribution.	Extreme	Potential	Extreme
Coastal Wetland Degradation	Climate impacts such as increased temperatures, increased runoff/precipitation, invasive species and drought act as stressors to coastal wetland environments. When considering coastal wetland degradation on a regional scale, sea level rise leads to the highest degree of habitat shifts and possible loss of salt marshes and important ecosystem services.	Extreme	Potential	Moderate
Freshwater Ecosystem Degradation	Rising temperature and changing precipitation patterns will lead to a reduction in water quality and changes in water quantity, resulting in changes to habitat quality in rivers, streams, ponds, lakes, and freshwater wetlands.	Moderate	Potential	Extreme
Forest Health Degradation	Warming temperatures, changing precipitation, increasing pest occurrence, more frequent and intense storms, and increased wildfire risk may cause a decline in forest health (e.g., biodiversity, biomass, resiliency) along with the loss of carbon sequestration and other ecosystem services. Impacts vary by forest type.	Major	Potential	Moderate
Shifting Distribution of Native and Invasive Species	Changing climatic conditions shift and eliminate suitable habitat for native species (flora and fauna), increase the risk of new species introductions, and increases competition from established invaders, potentially causing losses in native biodiversity and loss of culturally important specie.	Major	Potential	Moderate
Coastal Erosion	Climate change is expected to increase coastal erosion, primarily driven by sea level rise, particularly in areas not protected by wetlands (e.g., dunes, banks, beaches), which has conse-quences for water quality, land use, and habitat quality.	Moderate	Potential	Moderate
Soil Erosion	Increase in extreme precipitation results in increased erosion and loss of vegetation or changes in vegetation type, particularly along riverbanks but also in forests and in a number of landscapes.	Minimal	Potential	Moderate

Governance Sector Impacts

As noted in the Human and Infrastructure sector descriptions above, in the North and South Shore region there could be increased needs for statewide health services (connected to both extreme heat and air quality health impacts), food security support (which would expand the need for state-level SNAP programs), and emergency response as a result of climate change particularly connected to impassable road during extreme coastal storm events or more routine "high-tide" or "sunny-day" flooding of critical road infrastructure. In addition, many of these impacts can be expected to be concentrated among those residing in low-income block groups. At the same time, state and municipal revenues could be reduced, primarily through decreases in property values and therefore property tax revenue, but also tax losses associated with business interruptions. Projected property tax revenue losses statewide top $100 million by mid-century, and although figures are not available specifically for the North and South Shore region, the region could experience a significant portion of those losses given its exposure to coastal hazards.

Table 35. North and South Shores Urgency Rankings for Governance Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Increase in Demand for State and Municipal Government Services	Climate change serves as a threat multiplier, which can increase the need for expenditures to meet existing government service. Examples include capital, equipment, or operating costs for emergency response provision and state sponsored health programs.	Major	Potential	Moderate
Reduction in State and Municipal Revenues	State and municipal revenue streams impacted through property tax loss following structure damage of any type, from any hazard, and income and sales tax losses associated with business interruptions or effects on industrial activities.	Major	Limited	Moderate
Increase in Costs of Responding to Climate Migration	Costs and stresses to governments accommodating and/or preparing for forced and voluntary human migration of populations in response to climate threats or related economic pressures. Includes intra-state, inter-state, and international in- and out-migration, and is generally more abrupt than routine population changes in response to non-climate stressors (such as economic development or decline).	Minimal	Potential	Moderate
Damage to Coastal State and Municipal Buildings and Land	Risk to vulnerable state and municipal owned structures and other property from coastal flooding, wind, extreme heat, and extreme storms. Includes damage repair costs and service losses during closures.	Moderate	Limited	Moderate

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Increase in Need for State and Municipal Policy Review and Adaptation Coordination	State agencies and municipalities may require additional full-time employees and specialized training to meet the challenges of climate change. Specifically, state and municipal staff will need capacity to provide adaptation planning support and to review and modify policies in response to changing conditions and uncertainty associated with climate change.	Minimal	Potential	Minimal
Damage to Inland State and Municipal Buildings and Land	Risk to vulnerable state and municipal owned structures and other property from flooding, extreme heat, and extreme storms. Includes damage repair costs and service losses during closures.	Minimal	Limited	Moderate

Economy Sector Impacts

Climate change is projected to affect the economy in this region primarily through a Reduction in the Availability of Affordably Priced Housing availability and a Reduced Ability to Work due to high heat days and commute delays. All of the most urgent impacts in this sector are expected to disproportionately affect people living in EJ block groups. The current need for affordably priced housing in the North and South Shore region is exacerbated by relatively high housing prices overall in many parts of this region. While there may be less federally subsidized affordable housing in most parts of the North and South Shore region, this region has a relatively high potential inland flood risk to that housing which is within the 25th percentile housing cost on the private market – the annual expected flood damages to this class of housing in the region could be $7 million in 2030, $14 million in 2050 and $25 million annually by 2090. In addition, the region as a whole has a small amount of housing stock that is within this 25th percentile structure value, but the largest overall regional damage ratio.[68] The damage ratio is the annual expected flood damage per unit of structure value. Workers in the region are projected to experience a loss in ability to work through road delays driven by high tide flooding, commuter rail (an important connection from the region to the economic activity in Boston) delays due to track buckling on high heat days, and reduction in hours for high-risk workers (i.e., those exposed to outdoor weather) during extreme heat.

[68] American Community Survey property and structure value; U.S. EPA data at www.epa.gov/CIRA; and Project Team Analysis.

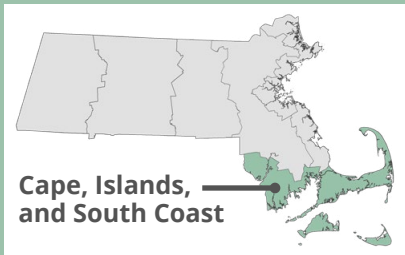
Table 36. North and South Shores Urgency Rankings for Economy Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Reduction in the Availability of Affordably Priced Housing	An increase in demand for housing that is affordable and a decrease in supply worsens the scarcity of affordably priced housing. Demand for housing that is affordable can result if people are forced to relocate either due to direct damage to existing housing or because of climate-related economic pressures. The supply of affordably priced housing is reduced due to direct physical damage from climate impacts and potentially higher construction costs to increase resilience to threats from climate change.	Major	Disproportionate	Extreme
Reduced Ability to Work	More frequent extreme heat days leads to lost wages and decreased productivity, as do increasing incidence of climate-induced health effects (e.g., asthma, allergies, vector borne disease, extreme heat). Weather-induced disruptions to transportation and ability to work may also lead to lost wages and worker productivity.	Extreme	Disproportionate	Moderate
Economic Losses from Commercial Structure Damage and Business Interruptions	Reduction in economic outputs during closures resulting from flooding and storm damage to places of business, as well as reductions in economic output due to extreme weather shutdowns, utility and infrastructure disruptions, and climate-driven supply chains issues.	Moderate	Disproportionate	Extreme
Damage to Tourist Attractions and Recreation Amenities	Changes to revenues in the tourism and recreation industry, particularly those associated with distinct New England seasons (e.g., winter recreation, foliage viewing), recreational fishing, beach recreation (i.e., reduction in beach width due to sea level rise and coastal erosion), and tourism related to vulnerable historical landmarks.	Moderate	Potential	Moderate
Decrease in Marine Fisheries and Aquaculture Productivity	Changes in water temperature regimes and acidification in the marine environment change fish habitat and alter commercial landings and revenue.	Major	Limited	Extreme
Decrease in Agricultural Productivity	Reduction in crop yields for major agricultural products including field crops and tree products due to changing temperature and precipitation patterns, extreme weather, loss of pollinators, saltwater intrusion, and others.	Moderate	Potential	Minimal

Cape, Islands, and South Coast Region Climate Impacts

The Commonwealth is already experiencing climate change impacts. The Cape, Islands, and South Coast region is particularly vulnerable to climate hazards such as sea level rise, storm surge, increasing temperatures, and more extreme precipitation. An understanding of the current and future impacts of climate change allows community decision-makers to best tailor adaptation plans to meet the specific challenges faced in this region. This report summarizes the highest urgency climate impacts across Human, Infrastructure, Natural Environment, Governance, and Economy sectors for the Cape, Islands, and South Coast region.

The highest urgency impacts are based on a review of the latest climate data developed for Massachusetts and a statewide assessment of potential climate impacts, informed by expert analysis and stakeholder engagement. The prioritized list will be an important input to the 2023 State Hazard Mitigation and Climate Adaptation Plan.



Regional Overview

Geography and Demographics*

- 39 cities and towns
- 658,000 people
- 20% minority
- 25% low-income
- 4% households with limited English language proficiency

Resources and Assets

- 317,000 residential properties
- 14,400 miles of road
- 148 miles of marine beach
- 18,800 acres of high marsh
- 648,000 acres of forest

**For definitions of these demographic terms, please see Volume II of this report.*

Regional Climate Outlook

2030	2050	2070	2090
NEAR TERM The summer mean temperature could increase by 3.6°F from the historical period (1950-2013), increasing tick activity and the risks of Lyme disease.	**MID-CENTURY** Sea surface temperatures increase by 3.1°F, reducing marine fish catch and increasing risks from harmful bacterial infections.	**MID-LATE CENTURY** The historical 10 percent annual chance daily rainfall event (2.4 to 4 inches) could occur five times more frequently.	**END OF CENTURY** Tropical cyclone frequency could increase by nearly 50 percent, leading to damage from storm surge, heavy rainfall, and high winds.

Most Urgent Impacts by Sector for the Cape, Islands, and South Coast Region

Defined by nearly 150 miles of sandy beaches and an active fisheries economy, life in this region is closely tied to marine and coastal resources. Many of the most urgent impacts relate to the interconnectedness of natural resources and economic activity in the region. Below are the top two impacts per sector (additional impacts are listed for tied scores). The bookmark icons identify unique regional priorities, meaning for each sector, impacts that are not a top three most urgent impact statewide but are a top two impact regionally.

Human

Increase in Vector Borne Diseases Incidence and Bacterial Infections, including West Nile Virus and Lyme disease due to more favorable conditions for ticks and mosquitoes.

Health and Cognitive Effects from Extreme Heat, Health Effects of Extreme Storms and Power Outages, Emergency Service Response Delays and Evacuation Disruptions, Reduction in Food Safety and Security, and **Damage to Cultural Resources** (tie scores).

Infrastructure

Damage to Electric Transmission and Utility Distribution Infrastructure associated with heat stress and extreme events.

Reduction in Clean Water Supply, particularly for communities reliant on well water.

Natural Environment

Marine Ecosystem Degradation because of warming, particularly in the Gulf of Maine, and ocean acidification.

Coastal Wetland Degradation from sea level rise and storm surge.

Coastal Erosion from sea level rise and storm surge, particularly in areas not protected by coastal wetlands.

Governance

Increase in Demand for State and Municipal Government Services, including emergency response, food assistance, and state-sponsored health care.

Reduction in State and Municipal Revenues, including a reduced property tax base due to coastal flood risk.

Economy

Reduction in the Availability of Affordably Priced Housing from direct damage (e.g., flooding) and the scarcity caused by increased demand.

Decrease in Marine Fisheries and Aquaculture Productivity from changing ocean temperatures and acidification, which leads to decreased catch and revenues, and impacts on related industries.

Featured Adaptation Effort

Coonamesset Bog Restoration

The Town of Falmouth removed a small dam, replaced an under-sized culvert, and restored a former cranberry bog to natural wetland and riverine habitat. This restoration led to increased native species, reduced invasives and a revived herring population.

Photo: Adam Soule

This Massachusetts Climate Change Assessment (Climate Assessment) evaluates a broad range of climate change risks to the Commonwealth, including impacts on human health, natural resources, and public and private assets. The Climate Assessment will serve as a core component of the 2023 update to the State Hazard Mitigation and Climate Adaptation Plan (SHMCAP), specifically concerning the detailed hazard risk assessment. The outputs of the Climate Assessment are designed to meet the requirements for State Hazard Mitigation Planning documents, and to directly inform and provide a risk prioritization focus to the Mitigation Strategy.

The Climate Assessment evaluates **impacts** from **climate stressors** (temperature, precipitation, sea level rise, etc.) and **climate hazards** (extreme heat, flooding, droughts, etc.) across five **sectors** in the state. The Assessment identifies statewide priority impacts that require near-term adaptation action as well as regional priorities for **seven regions** of the Commonwealth.

This report provides regional detail on the impacts of climate change in the Boston Harbor region of Massachusetts. For more details on the methods used in this assessment, please refer to the Statewide Report.

Regional Context

Regional Character and Demographics

The Cape, Islands, and South Coast region has the second lowest regional population but features two of the state's 10 most populous municipalities: New Bedford and Fall River. The region includes nine percent of the state's environmental justice block groups as designated by EEA, including a disproportionately high share of the low-income block groups (15 percent). The blue economy plays a significant role in the region and carries a degree of seasonality, with the service, hospitality, and tourism industries expanding during the summer months. Healthcare, manufacturing, and construction remain steady economic contributors throughout the year.[69,70]

The Cape, Islands, and South Coast have significantly more coastline than any other region. The region's key natural resources, including 150 miles of marine beach and more than twenty-two thousand acres of coastal wetlands, play a significant role in protecting coastal infrastructure and stimulating the regional economy. These resources face significant threats due to their exposure to climate-driven sea level rise and coastal storms.

The region boundary used for this assessment encompasses the Office of Coastal Zone Management's Cape and Islands and South Coast regions. The boundary includes the coastal areas of the Municipal Vulnerability Preparedness (MVP) program's Southeast region. All 39 of

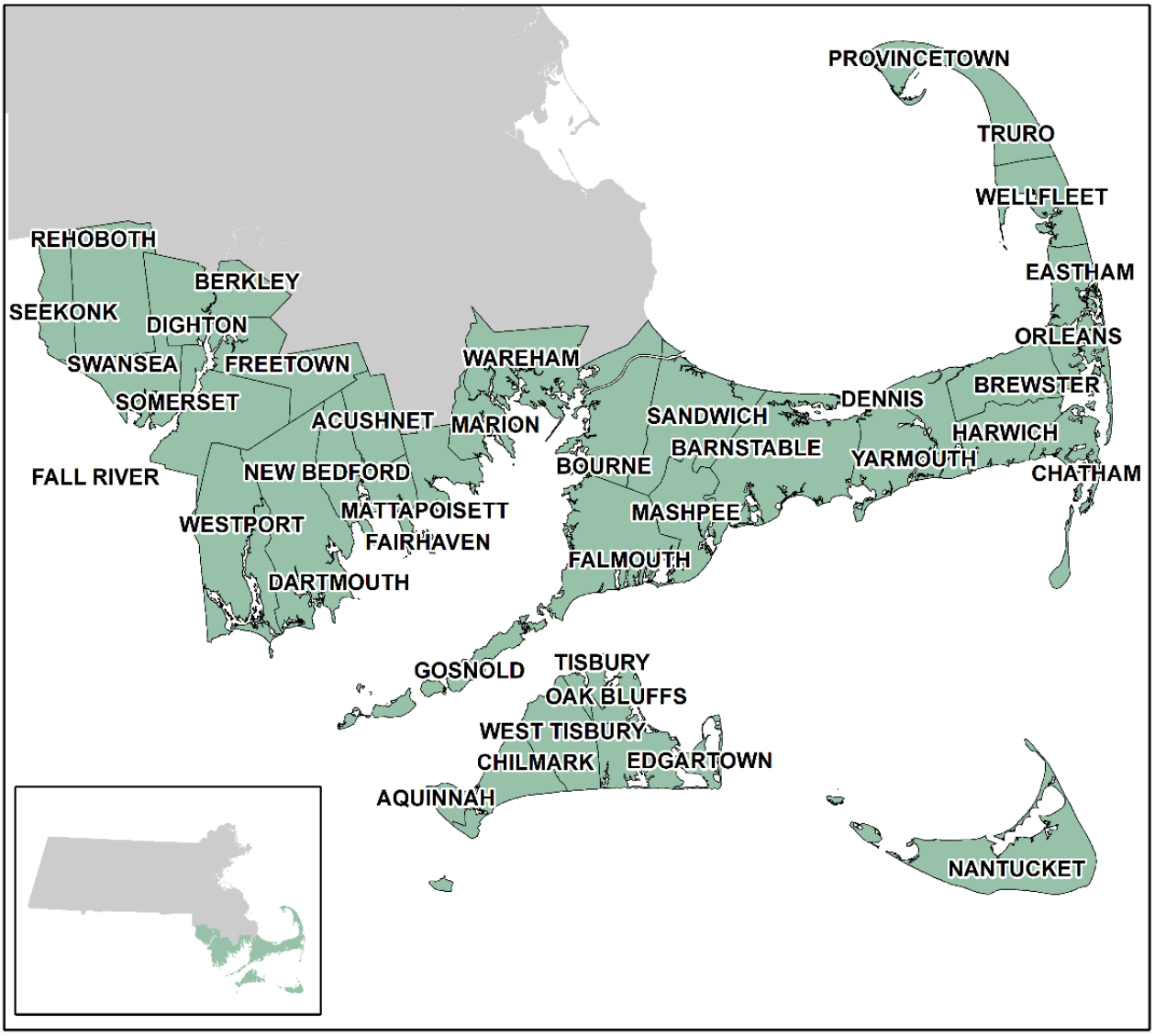
[69] Cape & Islands Workforce Development Board. The Cape & Islands Regional Workforce Blueprint. 2018. https://www.mass.gov/doc/ciwdb-regional-planning-blueprint-narrative/download

[70] Southeastern Massachusetts Workforce Development Team. Southeastern Massachusetts Labor Market Blueprint. 2018. https://www.mass.gov/doc/southeast-regional-workforce-skills-planning-initiative-regional-blueprint/download

the region's municipalities are engaged in climate adaptation and resilience planning and action through the MVP grant program.

Cities and Towns in the Cape, Islands, and South Coast Region

The MA Climate Change Assessment's Cape, Islands, and South Coast region includes these 39 cities and towns.



Highlights of Future Climate Projections

The most important climate risks for this region include increased coastal hazards, including sea surface temperature changes, coastal flooding, and the potential for hurricane force winds; and flooding associated with high rainfall events. Coastal hazards can affect built infrastructure, marine fisheries productivity, emergency service response times and evacuation routes, and the incidence of injuries. Some key findings of the climate change projections that may be important for this region over the 21st century include the following:

2030	2050	2070	2090
NEAR TERM	MID-CENTURY	MID-LATE CENTURY	END OF CENTURY
The summer mean temperature could increase by 3.6°F from the historical period (1950-2013), increasing tick activity and the risks of Lyme disease.	Sea surface temperatures increase by 3.1°F, reducing marine fish catch and increasing risks from harmful bacterial infections.	The historical 10 percent annual chance daily rainfall event (2.4 to 4 inches) could occur five times more frequently.	Tropical cyclone frequency could increase by nearly 50 percent, leading to damage from storm surge, heavy rainfall, and high winds.

Urgent Impacts in the Cape, Islands, and South Coast Region

Table 37 presents the two most urgent impacts per sector for the Cape, Islands, and South Coast region (more than two impacts are listed in the case of ties). The sections that follow provide additional details on the regional rankings for each sector. For more details on all impact assessment methodologies, see Chapter 2 of Volume II, the Statewide Report.

Table 37. Two Most Urgent Impacts by Sector for the Cape, Islands, and South Coast Region

Human Sector

- **Increase in Vector Borne Diseases Incidence and Bacterial Infections**, including West Nile Virus and Lyme disease due to more favorable conditions for ticks and mosquitoes.
- **Health and Cognitive Effects from Extreme Heat**, **Health Effects of Extreme Storms and Power Outages**, **Emergency Service Response Delays and Evacuation Disruptions**, **Reduction in Food Safety and Security**, and **Damage to Cultural Resources** (tie scores).

Infrastructure Sector

- **Damage to Electric Transmission and Distribution Infrastructure** associated with heat stress and extreme events.
- **Reduction in Clean Water Supply**, particularly for communities reliant on well water.

Natural Environment Sector

- **Marine Water Ecosystem Degradation** because of warming, particularly in the Gulf of Maine, and ocean acidification.
- **Coastal Wetland Degradation** from sea level rise and storm surge.
- **Coastal Erosion** from sea level rise and storm surge from sea level rise and storm surge, particularly in areas not protected by wetland.

Governance Sector

- **Increase in Demand for State and Municipal Government Services**, including emergency response, food assistance, and state-sponsored health care.
- **Reduction in State and Municipal Revenues,** including a reduced property tax base due to coastal flood risk.

Economy Sector

- **Reduction in the Availability of Affordably Priced Housing** from direct damage (e.g., flooding) and the scarcity caused by increased demand.
- **Decrease in Marine Fisheries and Aquaculture Productivity** from changing ocean temperatures and acidification, which leads to decreased catch and revenues, and impact on related industries.

Human Sector Impacts

The Increase in Vector Borne Diseases Incidence and Bacterial Infection, though not a high priority statewide, is the most urgent impact in the Cape, Islands, and South Coast region. Currently, approximately 460 cases of Lyme Disease are reported annually in this region.[71] One hundred and seventy additional annual cases of Lyme disease are projected to occur in the region in the near term (2030), with approximately 1,500 additional cases attributable to climate change by 2090.[72] There are approximately 4,500 annual cases of vibriosis in the Cape, Islands, and South Coast region, most associated with consumption of raw seafood, which accounts for 44 percent of statewide cases. In the near term (2030), an additional 1,200 cases attributable to climate change are projected to occur in the region, with approximately 5,400 additional cases by 2090.[73]

The next five impacts are tied in terms of urgency score. Cognitive Effects from Extreme Heat is a priority impact both statewide and in the Cape, Islands, and South Coast region. Areas such as Fall River, Hyannis, and Provincetown currently experience some of the hottest temperatures in the Commonwealth.[74] Currently, two annual premature deaths are attributable to extreme temperature in this region, but approximately 37 additional premature deaths per year are estimated as a result of climate change by the end of the century.[75] Coastal storms and flooding pose risks to evacuation routes, cultural sites, and electricity distribution systems, all of which can result in damages to people's health and wellbeing.

Table 38. Cape, Islands, & South Coast Urgency Rankings for Human Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Increase in Vector Borne Diseases Incidence and Bacterial Infections	Increase in incidence of West Nile Virus, Lyme disease, and other diseases, and associated fatal and nonfatal outcomes, as a result of changes in temperature and an extended seasons for vectors and/or impact on bacterial loads.	Extreme	Disproportionate	Moderate
Health and Cognitive Effects from Extreme Heat	Impacts of extreme heat episodes on health, learning, and workplace injuries - covers all health aspects of changes in frequency and severity of days with extreme temperatures.	Major	Potential	Moderate

[71] Massachusetts Department of Public Health. 2014, Lyme Disease Surveillance in Massachusetts. Available at https://www.mass.gov/lists/tick-borne-disease-surveillance-summaries-and-data#lyme-disease-surveillance-data- Data averaged for 2010 to 2014.

[72] Author's analysis of Couper, L.I., MacDonald, A.J., and Mordecai, E.A. 2020. Impact of prior and projected climate change on U.S. Lyme disease incidence. Global Change Biology, 27(4), 738-754.

[73] Sheahan, M., Gould, C., Neumann, J., Kinney, P., Hoffmann, S., Fant, C., Wang, X., and Kolian, M. 2022. The Influence of Climate Change on Vibriosis in the United States: Projected Health and Economic Impacts for the 21st Century. Environmental Health Perspectives. [accepted, in print]

[74] MAPC Land Surface Temperature Index. See Figure 15 in the main report of this Climate Assessment.

[75] Author's analysis of Mills, D., Schwartz, J., Lee, M., Sarofim, M., Jones, R., Lawson, M., Duckworth, M., and Deck, L. (2014). Climate change impacts on extreme temperature mortality in select metropolitan areas in the United States. *Climatic Change*, 131, 83-95.

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Health Effects of Extreme Storms and Power Outages	Power outages and flooding, which could increase with more frequent extreme events, lead to a range of morbidity and sometimes fatal health outcomes and an increase in requests for emergency services.	Major	Potential	Moderate
Emergency Service Response Delays and Evacuation Disruptions	Extreme storms cause delays in response time, potentially leading to loss of life. Extreme coastal storm surge events and inland flooding could flood evacuation routes, trapping residents, leading to increased loss of life and injuries.	Major	Potential	Moderate
Reduction in Food Safety and Security	Temperature increases, spoilage, and power outages can lead to increased food contamination. Changes in food production and supply chain disruption linked to climate change will worsen existing food insecurity.	Minimal	Disproportionate	Moderate
Damage to Cultural Resources	Climate stressors can damage important cultural resources that hold special value to residents of the Commonwealth.	Major	Potential	Moderate
Health Effects from Aeroallergens and Mold	Impacts from extended pollen seasons, particularly on people with asthma or hay fever, and increases in exposure to mold spores associated with more frequent flood events and higher humidity conditions.	Moderate	Potential	Moderate
Increase in Mental Health Stressors	Negative effects of weather and climate change on mental health, including a broad range of impacts on overall well-being associated mostly with temperature stress.	Moderate	Potential	Moderate
Health Effects from Degraded Air Quality	Impacts of climate-induced changes in ambient and indoor air quality on health (e.g., loss of life, health care costs, missed school). Focused on changes from the direct impact of climate on particulate matter and ozone air quality, and the resulting health effects associated with these pollutants.	Moderate	Limited	Extreme

Infrastructure Sector Impacts

Damage to Electric Transmission and Utility Distribution Infrastructure, from stressors such as extreme temperature, extreme rain, lightning, vegetation growth, wildfire activity, and coastal flooding in this region are considered major. Available estimates project repair costs could grow to an additional $5 million annually in 2050 and more than $12 million annually by 2090, and are roughly proportional on a per capita basis to other regions.[76] These estimates, however, omit damage that results from more frequent and intense wind storms, particularly high winds associated with tropical cyclones (the available estimates only consider storm surge). Available climate science suggests these damaging storms could be 47 percent more frequent in 2090.[77] Indirect impacts of power outages are addressed as part of other impact categories under the Human (health effects of power outages) and Economy (business interruption) sectors.

Reduction in Clean Water Supply is an urgent impact in this region, as much of the region relies on groundwater, as opposed to surface water, which can be more difficult to monitor for shortages. Climate change is projected to lead to reduced groundwater recharge through less infiltration (i.e., precipitation during high volume events cannot absorb in the ground as well as more frequent, lower volume events) and increased temperatures lead to more evaporation. This could lead to periods of stress in the aquifers, though it may also shift timing of aquifer recharge throughout the year rather than a true net decrease in recharge. Although a number of public water supplies and wells are located close to the coast in this region, a 2016 USGS study suggests that groundwater infiltration on the Cape is unlikely because of geological and hydrological features of the area (namely, the presence of surface water drainages that will dampen the response of the water table to sea level rise and the thick vadose zone, or unsaturated earth between the surface and the flowing groundwater table).[78]

Though Damage to Coastal Buildings and Ports and Damage to Roads and Loss of Road Service both are projected to have extreme magnitudes of consequence, disproportionate exposure to these impacts is limited compared to other impacts.

Table 39. Cape, Islands, & South Coast Urgency Rankings for Infrastructure Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Damage to Electric Transmission and Utility	Costs to repair transmission infrastructure failure associated with heat stress and extreme events that directly affect the transmission and distribution system. Includes wired	Major	Potential	Extreme

[76] Fant, C., Boehlert, B., Strzepek, K., Larsen, P., White, A., Gulati, S., Li, Y., & Martinich, J. (2020). Climate change impacts and costs to U.S. electricity transmission and distribution infrastructure. Energy, 195. Doi:10.1016/j.energy.2020.116899

[77] Marsooli, R., Lin, N., Emanuel, K., and Feng, K., 2019. Climate change exacerbates hurricane flood hazards along US Atlantic and Gulf Coasts in spatially varying patterns. Nature Communications. 10:3785, DOI:10.1038/s41467-019-11755-z

[78] Walter, D.A., McCobb, T.D., Masterson, J.P., and Fienen, M.N., 2016, Potential effects of sea-level rise on the depth to saturated sediments of the Sagamore and Monomoy flow lenses on Cape Cod, Massachusetts (ver. 1.1, October 18, 2016): U.S. Geological Survey Scientific Investigations Report 2016–5058, 55 p., http://dx.doi.org/10.3133/sir20165058.

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Distribution Infrastructure	communication and information technology systems.			
Reduction in Clean Water Supply	Addresses changes in water quantity and quality for water supplied for all human uses. Changes in precipitation patterns and saltwater intrusion can lead to impaired surface and groundwater supply available for municipal, industrial, commercial, and agricultural uses.	Major	Potential	Moderate
Damage to Coastal Buildings and Ports	Sea level rise, coastal erosion, and storm surge, as well as high wind events from tropical and extra-tropical storms, will cause increased damage to coastal structures, land, and related infrastructure such as ports and marinas.	Extreme	Limited	Moderate
Damage to Roads and Loss of Road Service	Damage to roads from extreme precipitation, flooding, and temperature increases the need for repair and maintenance, and indirect effects of increased vehicle operating costs from driving on roads in poor condition. Includes effects on bridges and culverts at road crossings.	Extreme	Limited	Moderate
Loss of Urban Tree Cover	Urban trees are susceptible to invasive pests and high heat/drought conditions and provide many services including mitigating heat island effects, pollution removal, etc.	Minimal	Disproportionate	Minimal
Increased Risk of Dam Overtopping or Failure	Climate change could lead to more frequent overtopping of some, or all of the state dam safety program designated High or Significant Hazard dams, causing flooding of downstream areas.	Minimal	Disproportionate	Minimal
Loss of Energy Production and Resources	Changes in temperature increase electricity demand and reduce production efficiency, requiring changes in the overall network cost of meeting electric demand. Effects on solar energy production potentially subject to flooding are also considered.	Moderate	Limited	Moderate
Damage to Inland Buildings	Addresses the risk of flooding to inland structures from rainfall (pluvial flooding) when drainage systems are overwhelmed by large rainstorms and rivers (fluvial flooding).	Minimal	Limited	Moderate

Note: Damage to Rails and Loss of Rail/Transit Service is not a significant impact in the region.

Natural Environment Sector Impacts

Marine and coastal natural environments are a defining characteristic of the Cape, Islands, and South Coast region. Natural resources are foundational to the identity of the region and support major industries such as fishing and tourism. Marine Ecosystem Degradation is the most urgent impact in this sector. Warming waters, increased ocean acidification, and increased pollution in nearshore areas after extreme precipitation events all lead to a degradation of the marine ecosystem in the region. Coastal Wetland Degradation is another priority concern in the region. The region is projected to experience near term gains in total salt

marsh area (with regularly flooded marsh expanding at a faster rate than the projected loss of irregularly flooded marsh), though by the end of the century, the rate of irregularly flooded marsh loss accelerates, resulting in a net loss of about 23 percent of saltmarsh in the region by 2070 and 64 percent by 2100.[79] The shoreline is also affected by Coastal Erosion. High rates of erosion pose a risk to the natural resources, including the loss of the beaches themselves, but also poses a significant threat to salt marsh habitat, and residential areas located immediately landward of the shoreline. The Cape, Islands, and South Shore region are experiencing the highest long-term rates of change in the Commonwealth – specifically Outer Cape Cod, and on Nantucket, and Martha's Vineyard. The highest long-term rates of change were observed on the Cape and Islands – specifically Outer Cape Cod, and on Nantucket, and Martha's Vineyard. The highest long-term erosion rate statewide of (23.6 feet per year) was observed on Muskeget Island, Nantucket. The highest long-term accretion rate statewide was observed on the leeward (west) side of Monomoy Island, Nantucket Sound (32.8 feet per year).[80]

Table 40. Cape, Islands, & South Coast Urgency Rankings for Natural Environment Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Marine Ecosystem Degradation	Changing sea surface temperatures, ocean acidification, and increased runoff nearshore alter habitat conditions in marine environments (including submerged aquatic vegetation) leading to changing marine species distribution.	Major	Potential	Extreme
Coastal Wetland Degradation	Climate impacts such as increased temperatures, increased runoff/precipitation, invasive species and drought act as stressors to coastal wetland environments. When considering coastal wetland degradation on a regional scale, sea level rise leads to the highest degree of habitat shifts and possible loss of salt marshes and important ecosystem services.	Extreme	Potential	Moderate
Coastal Erosion	Climate change, and particularly sea level rise, are expected to increase coastal erosion, particularly in areas not protected by wetlands (e.g., dunes, banks, beaches), which has consequences for water quality, land use, and habitat quality.	Extreme	Potential	Moderate
Freshwater Ecosystem Degradation	Rising temperature and changing precipitation patterns will lead to a reduction in water quality and changes in water quantity, resulting in changes to habitat quality in rivers, streams, ponds, lakes, and freshwater wetlands.	Moderate	Potential	Extreme

[79] Author's analysis of data from Woods Hole Group. 2016. Modeling the Effects of Sea-Level Rise on Coastal Wetlands. Prepared for Massachusetts Office of Coastal Zone Management. November 2016. Available at: https://www.mass.gov/files/documents/2018/12/07/czm-slamm-report-nov2016.pdf

[80] Author's analysis of data from CZM-USGS Massachusetts Shoreline Change Mapping and Analysis Program.

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Shifting Distribution of Native and Invasive Species	Changing climatic conditions shift and eliminate suitable habitat for native species (flora and fauna), increase the risk of new species introductions, and increases competition from established invaders, potentially causing losses in native biodiversity and loss of culturally important species.	Moderate	Potential	Extreme
Forest Health Degradation	Warming temperatures, changing precipitation, increasing pest occurrence, more frequent and intense storms, and increased wildfire risk may cause a decline in forest health (e.g., biodiversity, biomass, resiliency) along with the loss of carbon sequestration and other ecosystem services. Impacts vary by forest type.	Major	Potential	Moderate
Soil Erosion	Increase in extreme precipitation and potential loss in vegetation or changes in vegetation type, particularly along riverbanks but also in forests, on agricultural land, and in a number of landscapes.	Minimal	Potential	Extreme

Governance Sector Impacts

State and municipal revenues could be reduced with climate change, primarily through decreases in property values and therefore property tax revenue, but also tax losses associated with business interruptions and industry disruptions (e.g., tourism and fisheries). Projected property tax revenue losses statewide top $100 million by mid-century, and although figures are not available specifically for the Cape, Islands, and South Coast region, the region could experience a significant portion of those losses given its exposure to coastal hazards. This region also generates the most local taxes per capita from tourism of any region in the Commonwealth; impacts to the industry could significantly reduce local government revenues.[81]

At the same time, demand for government services could grow in response to increased needs for MassHealth (connected to extreme heat impacts on health), food security support (which would expand the need for state-level SNAP programs), and emergency response as a result of climate change (particularly connected to impassable roads during extreme coastal storm events or more routine “high-tide” or “sunny-day” flooding of critical road infrastructure). Many of these impacts can be expected to be concentrated among those residing in low-income block groups.

[81] Massachusetts Office of Travel & Tourism. 2020. 2019 Annual Report. Available at: https://www.visitma.com/wp-content/uploads/2020/06/2020_Annual_Report.pdf.

Table 41. Cape, Islands, & South Coast Urgency Rankings for Governance Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Increase in Demand for State and Municipal Government Services	Climate change serves as a threat multiplier, which can increase the need for expenditures to meet existing government service. Examples include capital, equipment, or operating costs for emergency response provision and state sponsored health programs.	Major	Potential	Moderate
Reduction in State and Municipal Revenues	State and municipal revenue streams impacted through property tax loss following structure damage of any type, from any hazard, and sales tax losses associated with business interruptions or effects on industrial activities.	Major	Potential	Moderate
Increase in Costs of Responding to Climate Migration	Costs and stresses to governments accommodating and/or preparing for forced and voluntary human migration of populations in response to climate threats or related economic pressures. Includes intra-state, inter-state, and international in- and out-migration, and is generally more abrupt than routine population changes in response to non-climate stressors (such as economic development or decline).	Minimal	Potential	Extreme
Damage to Coastal State and Municipal Buildings and Land	Risk to vulnerable state and municipal owned structures and other property from coastal flooding, wind, extreme heat, and extreme storms. Includes damage repair costs and service losses during closures.	Major	Limited	Moderate
Increase in Need for State and Municipal Policy Review and Adaptation Coordination	State agencies and municipalities may require additional full-time employees and specialized training to meet the challenges of climate change. Specifically, state and municipal staff will need capacity to provide adaptation planning support and to review and modify policies in response to changing conditions and uncertainty associated with climate change.	Minimal	Potential	Minimal
Damage to Inland State and Municipal Buildings and Land	Risk to vulnerable state and municipal owned structures and other property from flooding, extreme heat, and extreme storms. Includes damage repair costs and service losses during closures.	Minimal	Limited	Minimal

Economy Sector Impacts

The current need for affordably priced housing in the Cape, Islands, and South Coast region is strained particularly because of the need to house seasonal workers in the tourism and hospitality sector, amidst rapidly rising housing prices in the region. While there is less federally subsidized affordable housing in the region compared to other parts of the state, this region has the greatest potential inland and coastal flood risk to housing which is within the 25th

percentile housing cost on the private market – the annual expected flood damages to this type of housing in the region could be $16 million in 2030 but quickly grow to $25 million by 2050, $40 million by 2070, and $54 million by 2090.[82]

New Bedford was the top port in the U.S. by value of seafood landed in 2020, driven by landings of sea scallops, lobsters, and other high value commercial species.[83] With annual landings of approximately $650 million, marine fisheries are a significant driver of the economy in this region and in the state as a whole. Rising water temperatures and ocean acidification associated with climate change have been associated with decreased commercial harvests because of geographic shifts in species distributions poleward, altered seasonality of the fishing season, and changes to stock productivity, especially at middle and lower latitudes.[84] Marine fisheries impacts, exclusive to the coastal regions of the state, are projected to decrease by nearly $70 million by the end of the century because of climate change, with approximately 80 percent of impacts falling in the Cape, Islands, and South Coast region.[85]

Economic Losses from Commercial Structure Damage and Business Interruptions, particularly from flooding and power outages, could affect all industries, including tourism. Climate-driven damage to infrastructure, loss of beaches, and decreases in seafood production threaten the tourism industry, which is an important economic driver in the region. Cranberry harvests could also be affected by climate change. A recent study in southeastern Massachusetts found cranberry plants flower two days earlier for every one-degree Celsius increase in May temperatures. This can lead to uncertainty in planting and harvest times for growers.[86]

[82] American Community Survey property and structure value; U.S. EPA data at www.epa.gov/CIRA; and Project Team Analysis

[83] National Marine Fisheries Service. 2022. Fisheries of the United States, 2020. U.S. Department of Commerce, NOAA Current Fishery Statistics No. 2020. Available at: https://www.fisheries.noaa.gov/national/sustainable-fisheries/fisheries-united-states

[84] Morley, J.W., Selden, R.L., Latour, R.J., Frolicher, T.L., Seagraves, R.J., and Pinsky, M.L. 2018. Projecting shifts in thermal habitat for 686 species on the North American continental shelf. PLoS ONE, 13(5), e0196127; and

[85] Moore, C., Morley, J.W., Morrison, B., Kolian, M., Horsch, E., Frolicher, T., Pinsky, M.L., and Griffis, R. 2021. Estimating the Economic Impacts of Climate Change on 16 Major US Fisheries. Climate Change Economics, 12(1), 2150002.

[86] Ellwood, E.R., Playfair, S.R., Polgar, C.A. and Primack, R.B., 2014. Cranberry flowering times and climate change in southern Massachusetts. International Journal of Biometeorology, 58(7), pp.1693-1697.

Table 42. Cape, Islands, & South Coast Urgency Rankings for Economy Sector Impacts

Impact	Description	Magnitude of Consequence	Disproportionate Exposure	Adaptation Gap
Reduction in the Availability of Affordably Priced Housing	An increase in demand for housing that is affordable and a decrease in supply worsens the scarcity of affordably priced housing. Demand for housing that is affordable can result if people are forced to relocate either due to direct damage to existing housing or because of climate-related economic pressures. The supply of affordably priced housing is reduced due to direct physical damage from climate impacts and potentially higher construction costs to increase resilience to threats from climate change.	Major	Disproportionate	Extreme
Decrease in Marine Fisheries and Aquaculture Productivity	Changes in water temperature regimes and acidification in the marine environment change fish habitat and alter commercial landings and revenue, including effects on related industries.	Extreme	Disproportionate	Moderate
Economic Losses from Commercial Structure Damage and Business Interruptions	Reduction in economic outputs during closures resulting from flooding and storm damage to places of business, as well as reductions in economic output due to extreme weather shutdowns, utility and infrastructure disruptions, and climate-driven supply chains issues.	Moderate	Disproportionate	Extreme
Damage to Tourist Attractions and Recreation Amenities	Changes to revenues in the tourism and recreation industry, particularly those associated with distinct New England seasons (e.g., winter recreation, foliage viewing), recreational fishing, beach recreation (i.e., reduction in beach width due to sea level rise and coastal erosion), and tourism related to vulnerable historical landmarks.	Major	Disproportionate	Moderate
Reduced Ability to Work	More frequent extreme heat days leads to lost wages and decreased productivity, as do increasing incidence of climate-induced health effects (e.g., asthma, allergies, vector borne disease, extreme heat). Weather-induced disruptions to transportation and ability to work may also lead to lost wages and worker productivity. Impacts are felt most by workers in outdoor industries, those who rely on public transportation, and those who care for others at home.	Extreme	Potential	Moderate
Decrease in Agricultural Productivity	Reduction in crop yields for major agricultural products including field crops and tree products due to changing temperature and precipitation patterns, extreme weather, loss of pollinators, saltwater intrusion, and others.	Moderate	Potential	Moderate